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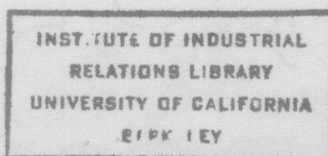
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The Development of Operations Research
and Its Influence on Management
(Part II)

What is the Value of
Operations Research?

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THE DEVELOPMENT OF OPERATIONS RESEARCH
AND ITS INFLUENCE ON MANAGEMENT
(Conclusion)

by Joseph P. Murray, M.B.A.

The recent transition of operations research from the military to industry is a favorable progression of development. However, serious consideration has not been given to the location of the operations research group in the organizational structure. The cost factor, and the freedom of action required by the analyst have handicapped the growth within an organization. The other alternative of hiring an outside operations research consultant group may be an answer for some companies.

Organization within a company. The need for freedom of action by the operations analyst was confirmed in World War II. In order to build faith in their techniques and confidence in their methods the operations research workers must be free from pressure groups. It is necessary that personnel engaged in operations research have free access to all levels of the organizational structure. They must be able to contact the board of directors and at the same time they should be permitted to observe the detailed operations at the lower levels.

The problems that are presented to an operations research section are complex and may involve an overall review of the company's operations. The operations research group attempts to solve the problem of the overall company balance in terms of the desired objectives.

The requirements of the operations research group would indicate that this section should be established between the board of directors and the president. In this position the operations research group could view the total organizational balance and still be allowed to transcend to lower

echelons for specific problems. If it is to secure the best courses of action and the best overall balance objective, the operations research section cannot be subordinated to a sales manager or to a manufacturing vice president.

The operations research group can assist the board of directors in formulating long range plans, the development of policies, and programs of action. It can do this by presenting to management the alternative courses of action in such a manner that the decision making will be simplified.

Whenever bottlenecks and trouble areas occur within the company the operations research group can study the situation. After careful analysis, suitable plans for alleviating the trouble areas will be presented, and the executive will decide on the best course of action.

The salaries of these highly technical personnel will be high. Perhaps only large companies can establish an operations research section within the company. Some executives will be concerned about the control and measure of effectiveness of the research groups. What quantitative measure can the executive apply to evaluate the benefits of a research group? Will an operations research section pay for itself? This is a perplexing question to an executive. The successful progress of operations research groups in the field of management will assist the executive in this determination.

The growing success in solving complex management problems by the operations research groups has convinced some large companies that a section should be established within a company. It has been estimated that companies with thirty million or more in dollar sales will establish small operations research departments. The cost of a three-man research department may be \$25,000 to \$40,000 for six months. When the size of the operations research section increases the cost of that section will increase. The other alternative for

companies is to employ an outside research group.

Outside consultants. The outside operations research group will probably be utilized by smaller companies. The selling of this service to smaller companies is a major problem. The impatience on the part of management for solutions is a difficult obstacle to overcome; in addition, management doesn't like to make expenditures for an item that is difficult to control and measure. The techniques employed are sometimes complicated and management cannot understand them. The methods and procedures employed by scientists create suspicion in the minds of some executives.

The outside consulting firms that are engaged in operations research can assist in the favorable growth of operations research within a company and outside a company. The factor of overselling operations research to small firms should be eliminated. If a consulting firm selects its problems recklessly without recognizing the limitations of operations research, the stage for regression and disappointment is established. It is important that the problems and areas be carefully identified for study by operations research.

Another problem area that will face the development of operations research groups will be incompetent personnel holding themselves out as operations analysts. A few disappointments on the part of management can retard the growth of operations research groups. The need for qualified personnel in this field of endeavor is a critical problem.

Limited personnel. The formal training of qualified personnel for careers in operations research is limited. In 1948, the Massachusetts Institute of Technology in conjunction with the Navy established a course

in non military applications of operations research. The Case Institute of Technology is the first to grant a degree of Master of Science in operations research. And in 1952, Columbia University and the John Hopkins University presented their first courses in operations research.¹

It appears that the personnel manpower must be recruited from within the active scientific specialty fields. However, it is believed that personnel with business background could aid in the selling and communication problems that are confronting the operations research groups.

The present emphasis for personnel recruitment is in the scientific fields. This requirement is based on the fact that the scientist automatically employs the scientific approach and methodology. He is trained to be skeptical and to look for basic causes. He is familiar with the techniques of observations, tests, models, and experimentation.

The individual entering operations research work in management must be patient and tolerant. He will have to understand the views of management and attempt to present his findings in a clear and understandable manner. If the individual's background is entirely in the sciences, it will be necessary that he acquaint himself with a working knowledge of business relationships.

Individual qualifications for operations research work are high but these qualifications are necessary at the present time. With the increased utilization of electronic computing machines it would appear that the qualifications may be lowered slightly.

Interest is being created in this field of endeavor by universities,

¹Joseph F. McCloskey and Florence N. Trefethen (eds.), Operations Research for Management (first edition: Maryland: The John Hopkins Press, 1954), p. 34.

seminars, research publications, and active consulting firms. As the interest broadens more young men will probably enter operations research as a career.

EVALUATION OF OPERATIONS RESEARCH

The development and growth of operations research has reached a stage whereby an evaluation can be made of its contributions, its limitations and its future growth.

CONTRIBUTIONS

Operations research proved itself in World War II and it has made favorable strides in industry. Many complex management problems have been solved with the aid of operations research groups. It has extended the scientific management movement and provided a framework for further development.

The utilization of operations research provides several advantages to a company. It will highlight and discover the real causes for the business situation or status. Complex problems are solved by new concepts and methods of analysis. It applies organized, logical, and effective thinking to data that presently exists within a company.

Operations research will develop the basis for decisions by outlining alternate courses of action. In this way it will assist the executive in decision making. The quantitative approach will eliminate the hunches and guesses and enable the executive to make decisions based on facts.

The application of operations research may be a competitive advantage for a company. The results obtained in employing the services of operations research may far outweigh the costs. The trouble areas will probably be removed before a serious breakdown in operations occurs. The optimum balance

in overall operations will probably be obtained. Inventories and production requirements can oftentimes be correctly balanced to the sales program.

With the introduction of automation, the human factor is reduced and this will decrease the number of intangibles that must be encountered. The foundation is gradually being formed for a higher degree of accurate predictions and operational pattern behaviors.

The availability of electronic computing machines will permit a greater utilization of large masses of statistical factual data. The laborious computations can be handled by the machines and the element of time in research studies will be reduced.

Operations research applies a scientific approach and attempts to solve its problems by providing a balanced equation. The optimum course of action or the desired operating situation can be expressed in a mathematical equation. When component parts of the equation change, it requires a modification in other parts of the equation to maintain a balance.

The combined team approach has permitted a more comprehensive view of the business complexities. With the blending of the varied scientific minds, the techniques and tools of operations research have been expanded. The formulas and techniques in one field of endeavor can oftentimes be applied to other fields of endeavor. The basic problems are disclosed and the periods of frustration are reduced.

The operations research group provides a measure of effectiveness for business operations. The yardstick or standard of performance may vary from a return on your investment and net dollar profit to productive hours. The factors and component parts may be expressed in a common denominator of dollar cost. The real objective will be highlighted and the corollary goals

or inconsistent goals will be disclosed. The diverse goals of customer service, production economy, and investment can be expressed in terms of cost. These different costs can be expressed in an algebraic equation whereby their interrelationships are recognized, compared, and analyzed. The algebraic equation can be used to forecast future situations by varying the elements in the equation.

It is intended that operations research supplement the present existing services of statistics, accounting, marketing research, engineering, and industrial engineering. The services of these sections will be utilized in the solution of the problems.

Operations research may be utilized for broad areas and it may also be utilized for trouble spots and selected areas. It may be a one time study or a continuing study depending on the situation and the desires of the company. This flexible approach is a desirable characteristic of operations research.

There are many contributions that have been made by operations research. The number of problems and the scope of coverage that can be handled by the operations research group are in a constant stage of development and expansion. However, one should also recognize that certain limitations exist in operations research and they should be reviewed at this time.

LIMITATIONS

There are several problems confronting the development and growth of operations research groups. The primary problem is qualified personnel to engage in this type of work. There are very few schools of higher learning that provide courses in operations research. It has become

necessary to recruit personnel from the scientific and technical careers to supplement the present staff of operations research groups. The qualification requirements of the individual are established at a high level and restrict the number of personnel that can be considered. Personnel that do possess the proper qualifications are often hesitant about leaving their present position. The military demands and the ever growing atomic field are limiting the supply of available qualified men.

If an operations group is assembled within a company or a consulting group is established there are still problems to be confronted. The cost factor has prohibited some companies from establishing a section within the organization or employing outside consultants. It has been estimated that the cost of three operation analysts with assistants would cost in excess of \$30,000 for a six month period. The fees of a consulting firm may vary from \$30,000 to \$100,000 or more, depending on the time element, the personnel employed, and the difficulties encountered. It is assumed that companies with 30 million to 50 million dollars in sales will have their own operations research departments. The outside consultants will serve the small and intermediate size firm.

The exact location of the operations research section in an organizational structure has not been clearly established. Some executives would rather have the research section at an intermediate level until the particular section has demonstrated its success. In other instances executives have desired that the operations research group be placed as an administrative aid to the top executive. The differences of opinion in the location of this operations research group will have to be resolved.

There is a definite problem of installation connected with the

operations research group. The scientist and management do not always appreciate each other's problems. Management is usually impatient in expecting tangible results while the scientist must be patient in seeking the true causes for a situation. The scientist requires freedom of action and authority in conducting his studies. Management does not appreciate this uncontrolled freedom and the inability to measure the effectiveness of the group itself. Another factor in the installation of operations research is communication. The highly technical mathematical formulas employed by the operations research groups cannot be understood by management. The inability of management to understand the work of operations research may prevent management from following the work of the group. This may cause suspicion and distrust of the operations research group on the part of management.

The problem of overselling operations research is closely allied to the incompetence of some practitioners in the field. The limitations of operations research must be recognized and it cannot be utilized as a cure-all for business ills. The misapplication of operations research can only bring disappointment to all concerned. Some unqualified individuals will hold themselves out as research analysts in order to obtain large fees yet the service rendered will be inferior.

Operations research is still in the pioneering stage and the creative ability of the analyst must be depended upon. It should also be noted that the scientific approach is time consuming and the research worker is torn between the applied science and the basic science. The removal of the subjective factor on the part of the analyst may also present a problem.

The problems that are presented must be capable of being expressed

quantitatively. There are many intangibles that cannot be expressed in numbers although it may be possible to rank one intangible over another.

The actual decision making must still remain with the executive. Alternative courses of action can be presented by the operations research group, but the actual selection of the course of action is the responsibility of the executive. Human satisfactions, moral and ethical values, responsibilities towards employees, stockholders, and the community will continue to be the function of executive judgment.

The major limitations of operations research are personnel problems, prohibitive cost, installation problems, and communications. The removal of these limitations are necessary to permit any large expanded development in this field.

FUTURE GROWTH

The publication of articles on operations research is creating an interest on the part of management to find out more about it. Management societies, operations research workers, and some universities are contributing to the education of business executives in operations research. Seminars are being offered to acquaint the business executive with the uses and application of operations research. This plan of action should at least establish a wedge in the door of management and with a sound indoctrination program the door may remain open.

The personnel problem is being given consideration and a few universities are taking steps to include courses in operations research as part of the curriculum. The needs of management and the attractive salaries of industry may assist in seduring qualified men from the technical and

scientific fields. With the development and progression of operations research, it is noted that types of individuals assigned to operations research are expanding. Human sciences are important and they must be integrated with the physical and mathematical sciences. The equation of proper balance cannot disregard the human relationships; they must be fitted into the pattern to assume a proper place. The Rand Corporation employs political scientists, psychologists, and sociologists as well as astronomers, chemists, and engineers. The inclusion of business administrators may strengthen the personnel group of operations research. Future development may require a change in the present personnel package and this is being recognized by those engaged in operations research work.

Prohibitive cost may be alleviated by the competitive factor. When more personnel enter the field and methods are improved, the cost of operations research will indicate a certain amount of decrease. The introduction of electronic computing machines will assist in alleviating the cost of computing the laborious formulas. However, in the next few years the cost of employing operations research groups will be high.

The problems of installation and communication are gradually being solved. Scientists are appreciating the problems of an executive and the executive is gaining an insight into the problems of the scientist. The presentation of the methods and findings must be simplified for the executive. Control devices must be established to measure the progress of the operations research group.

With the gradual alleviation of the internal problem areas and the indoctrination of management in the possible uses of operations research a step toward progress is being made. It will be a few years before

operations research will be generally accepted but it does appear that it will occupy a definite position in the business of the future.

SUMMARY AND CONCLUSION

In reviewing the development of operations research during World War II it is noted that scientific methodology was employed. The recognition of the scientific approach to business problems can be traced to the pioneers of methodology called scientific management.

The scientific management movement concerned itself with eliminating the inefficiencies in business and approaching business problems with scientific methods. Frederick Winslow Taylor recognized the need for the scientific approach to replace the existing methods of guesses and hunches. A few of the other personalities that developed and fostered this movement were Frank Gilbreth, Henry L. Gantt, Harrington Emerson, Morris Cooke and Henri Fayol. These men developed better work methods and principles of management. They constructed the framework for the standardization of procedures, motion and time study, organization structures, production control, quality control, cost control, functional analysis, and methods analysis. The foundation for the acceptance of the scientific methodology by management had been laid by non scientists.

Extension of the scientific methods as practiced in physics, biology, chemistry, and other sciences, is the basis of the new approach to business problems. Today scientists recognize that the methods of approach that are developed in one scientific field can also be applied in other fields. An analysis of the underlying causes of action in the varied fields has revealed that certain similarities exist and that the differences are

usually apparent and not basic.

During World War II the combined and integrated scientific approach was developed in answer to military needs. Prior to the war the British had been experimenting with civilian problem areas utilizing an operational research approach. The war accelerated the development and growth of the operational research approach in England and in the United States. Problems that were handled during the war ranged from detection of U-boats by radar, improving the bombing and mine laying techniques of air crews, to the evaluation of maintenance equipment and the qualification of air and ground personnel. The success of operations research in the military assisted in the transition of this approach to civilian and industrial uses.

In reviewing the basic requirements in the collection of data there are certain fundamentals that must be considered. The collector of data should be as close to the source of information as is possible. This enables the field worker to gather primary source material or at least authoritative factual data that can be verified. The accuracy and reliability of the facts must be regarded as the most important criteria in gathering data.

There are certain intangibles that must be recognized in the collection of data and some of these intangibles must be considered in the light of the collector or observer of facts. Emotions, opinions, assumptions, inferences, bias, and prejudice must be controlled. The collector must also guard against unproven theories, fallacies and distortions. Intangibles in research must be recognized and restraints applied if necessary.

The quantitative study of data requires that the material be expressed in definite numbers or at least in order of numerical magnitude. However, the quantitative aspects of operations research are not the total

solution to a problem. The executive must supplement these quantitative aspects with quality factors bearing on the problem.

There are four fundamental concepts to the practice of operations research; the model, the measure of effectiveness, the role of experimentation, and the necessity for decision.

In the model, it is necessary to duplicate as near as possible, the actual conditions that the proposed situation will be subjected to in its operations. The uncertainties must be recognized and treated accordingly. The mathematical models are expressed in algebraic equations. Elements in the equation are varied in order to obtain the optimum in the balanced business status and to permit forecasting future situations.

The measure of effectiveness is the standard of performance and this may vary from return on your investment to productive hours. The true goals must be disclosed and the inconsistent goals eliminated. The diverse goals of customer service, production economy and investment can be expressed in terms of cost.

The role of experimentation plays an important part in the collection of data and testing the validity of experiments and conclusions.

Operations research will furnish alternative courses of action whereby a decision must be made. The analyst will clarify the relations between several courses of action and indicate the most favorable course in terms of the objective. The decision will still have to be made by the executive in management.

There are several methods and techniques that the operations research group applies to management problems. Linear programming has been utilized in solving problems involving product mix, plant layout, policy control,

and scheduling. The problem of material selection for manufacturing a three piece mechanism was solved by the symbolic logic method. The information theory lends itself to problems of paperwork and flow problems that would be analogous to a communication system. In reviewing these methods and others, it should be recognized that the existing methods, which management is currently utilizing, are also a part of the operations research kit.

The provision for a operations research group within an organization has been slow. This condition has resulted from the specific requirements of such a group, the cost factor, the lack of qualified personnel, and the problems surrounding the installation of operations research. It has been estimated that large companies with sales in excess of \$30 million will establish a small operations research group within the organization. Consultants will serve the intermediate and small firms.

The development of operations research and its application to management is a definite contribution to management improvement. Expanding business enterprises and the complex problems associated with them, demand new and improved managerial methods and controls.

Operations research is currently contributing knowledge, techniques, and formulas to aid management in selecting the best courses of actions. The development of policies, plans, and programs of action are being simplified with the new approach. The combined and integrated scientific approach has assisted in the development of optimum equations of balance. Future operations can be more accurately predicted by varying the elements in the equations.

The limitations of operations research should be recognized. Management should not expect miracles and it should realize that operations

research is not a cure for all business ills.

Operations research identifies the number of facts that exist in business and converts these facts to numbers. With the processes of experimentation operations research is able to test the completeness of the model and to predict with a greater degree of accuracy the probable outcome of a given situation. It will disclose basic problems and develop alternate courses of action to solve the problems. Operations research will assist in the proper alignment of programs and policies to the true objectives. Management should recognize that the decision making has not been taken away and that the executive is still responsible for decisions.

There are certain internal limitations of operations research that should be noted. The shortage of qualified personnel, the prohibitive cost, installation problems, and communication problems. These limitations are slowly being alleviated but they do exist and should be recognized.

With the increased utilization of electronic computing machines the demand for the services of operation research will be increased. It is believed that operations research should occupy a place in the business organizational structure between the board of directors and the president.

Operations research is exerting a favorable influence on management. In the next few years one will probably observe the gradual installation of operations research groups into more large enterprises. The consulting firm type of operations research will continue to serve the needs of the intermediate and small enterprise.

Operations research has made a definite contribution to the growth of management and its influence on business will be greater in the future years.

WHAT IS THE VALUE OF OPERATIONS RESEARCH?

by Herbert B. Hubbard

AN EVALUATION OF OPERATIONS RESEARCH

The purpose of this study is to objectively evaluate the concept of Operations Research--to determine what it is, whether or not it is a new concept, its techniques in general, its limitations, its possible value in the decision-making process, and possible applications of Operations Research to airline operations.

Most articles in the trade journals, magazines, etc. do not fill the basic need for information on Operations Research. They are generally written by people who are more interested in the news value of the new term than in providing worthwhile information for their readers. Popular articles are often excellent selling jobs which overemphasize the positive rather than present a more balanced picture and realistic appraisal.

The nature of Operations Research and the scope of the work and the types of problems which it attempts to undertake make difficult a definition of it in precise terms and characteristics. The lack of a unified theory and basic concepts, attendant with the early stage of its development, makes it difficult to understand what is new about Operations Research and how it differs from already available services and techniques. Furthermore, the tendency of companies to keep the results of Operations Research investigations secret has prevented a comprehensive appraisal of its accomplishments.

WHAT IS NOT INCLUDED IN THE STUDY

Emphasis will not be placed on specific techniques and methods of

Operations Research (such as linear programming, queuing theory, decisions theory, etc.), nor on their further refinement, nor on specific case studies that are not generalized. Such an analysis would be far beyond the scope of this paper and their inclusion would dilute the basic objectives of this study.

POSSIBLE AIRLINE APPLICATIONS

If the application of Operations Research can be shown of value in certain areas, an attempt will be made to determine the most fruitful areas of application in airline operations and some of the basic concepts and factors involved in those applications.

WHAT IS OPERATIONS RESEARCH?

WHAT OPERATIONS RESEARCH IS NOT

Operations Research is not a cure-all or panacea for business problems. It is not a novel, startling, and unproven technology, nor is it a new kind of gadgetry with a limited kit of specialized tools. Operations Research is not distinguished by either its objective or its subject matter. Many aspects of the method have been used separately and collectively for a long time.¹

Many problems and some definite limitations are inherent in the concept. Business managers must become aware of these problems and limitations to prevent it from developing into a fad rather than a useful tool of management.

¹Russell L. Ackoff, "Operations Research in Business and Industry," Industrial Quality Control, May, 1952, p. 41.

EXTENSION OF SCIENTIFIC METHODS IN INDUSTRY

Operations Research is simply the further extension of scientific methods in industry, following the basic ideas of Henri Fayol and expanding the application of the basic principles of Frederick W. Taylor. The use of Operations Research can be regarded as the logical continuation of the evolution towards better management. Possibly the earliest transfer of scientific methods to the business environment was accomplished by Taylor in the study of time and motion. He saw the relationship to the experimental scientific method and applied it with great success to physical work situations. Unfortunately, Taylor did not apply his basic principles to the broader areas of management.

Since the days of Taylor and his contemporaries, relatively little true research on operations took place until recent years. This may have been due in part to the inability to handle the complex interactions and multivariate problems involved and to the lack of means of collecting and processing data in the volume necessary. However, in recent years more factual data is being used in business and companies are using research to an increasing degree. There is a definite trend towards running business with more quantitative and factual information.

BROAD OVERALL APPROACH

Managers faced with the problems of technological and economic complexity must look at the whole of a situation to provide that necessary unity of direction, while also obtaining the benefits of functional specialization. The broad needs and opportunities for Operations Research

are in terms of the whole business problem, not in terms of the isolated parts.²

Operations Research is concerned with reaching an understanding of the whole operation and its field--the operation, the operators, that which is operated upon and that which is used in the operation, and the environment surrounding the operation. It should evaluate the effects of different alternatives upon predetermined yardsticks and thereby reveal incompatible goals and establish the best balance between them.

Operations Research will not only be the application of set formulas and tools to industrial problems, as is done in industrial engineering. Instead of dealing with a specific technical area, it could be of greatest value in attempting to maximize the overall results of the company operation, rather than the results of its subparts, in a formal and quantitative manner.

APPLICATION OF METHODS FROM SCIENTIFIC FIELDS

Many business situations have a marked similarity to those in the natural sciences and mathematics that have been defined and solved during the past century. The basic process of Operations Research is establishing an analogy between a given business situation and some known logical structure in science and mathematics. Operations Research is not new because it utilizes those techniques which have been developed in mathematics and other sciences to solve problems.

²Ibid, p. 43.

Co-disciplinary Approach. Team research, with representatives from different scientific disciplines, has been advocated for solving complex business relationships and problems. Most processes which apply to one science also have their analogous processes are different in the different fields. For this reason, potential benefits can be derived from various disciplines because of the differences in the methods of attacking these general problems.³ This approach is not new nor unique with Operations Research.

New Mathematical Techniques. The complicated mathematical techniques employed by Operations Research may have been overemphasized in the popular literature, but many operations can and should be submitted to quantitative analysis. A considerable number of mathematical developments and derived techniques have been evolved during the past twenty years. These new techniques can handle complex problems that previously had been considered too chaotic, too random, too complex, or too uncertain for any other treatment than unaided intuition and judgment. The most fundamental mathematical development is probability theory, from which are derived many lesser techniques such as sampling theory, waiting line theory, Monte Carlo method, statistical quality control, etc.

Business events are probabilistic in nature—a given event will not always follow another, but there may be a greater expectancy that this event, rather than another, will follow. Until the likelihood of various

³Ibid, p. 44.

events occurring is measured quantitatively by probability theory, data by themselves may tend to be more a curiosity than a workable body of fact. Although it is not possible to accurately predict the action or reactions of a single item, it is now possible to make good estimates of the actions or reactions of a group of items if their basic characteristics and relationships are understood.⁴ The concept of a model (a paper representation of the actual operation) is basic to many studies.

Statistics is the most commonly used tool of Operations Research for screening a mass of data for analysis. Other mathematical techniques used at present include linear programming, symbolic logic, search theory, and analysis of variance. Further development is required before the theory of games can be of general use.

Operations Research will become a more powerful management tool as better mathematical tools are developed in the future.

Quantitative Data. Since the early 1900's business firms and government agencies have become increasingly aware of the value of statistical information and are collecting quantitative facts on many operations. Operations Research could not be applied to complex problems until basic quantitative data had been collected. The most frequent applications have been in the areas of production scheduling and inventory control because the variables in production are easily quantified and data are readily available.

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⁴M. L. Hurni, "Observations on Operations Research," presented at the Second Annual Meeting of the Operations Research Society of America, Chicago, Illinois, May 22, 1954. p. 20.

Operations Research has also proven effective in other phases of business where the general goal likewise consisted of getting the maximum use out of some limited resource.

High-Speed Computers. Business problems are difficult to solve because the number of variables to be considered are generally quite large. Many of the practical problems of business are essentially computational because of the intricate and involved mathematical relationships. The sheer quantity of material to be handled has been a serious obstacle in the past. However, in recent years, the solution of problems has been greatly facilitated as the result of mathematical and statistical developments in conjunction with work on economical mass-data handling and high-speed computational devices. On the other hand, in those cases where the operations are not highly repetitive, the economies to be realized by more elaborate computers would be outweighed by the costs of programming them.

CAN OPERATIONS RESEARCH AID DECISION-MAKING?

PRESENT DECISION-MAKING METHODS

The job of the executive is to make decisions. The mature judgment and background experience of the executive combined with whatever facts are available plus some shrewd guessing is the method generally used in deciding between the various alternatives possible and selecting that decision which appears to be the best one.

Often a decision appears to follow logically from a given situation. However, the situation itself is subject to personal interpretation.

Therefore prejudice, habit, frame of mind, and tradition may influence the decision. Tradition may be responsible where the frame of mind of the executive blocks a proper evaluation of the problem. Traditional operating procedures tend to block a clear and objective consideration of problems. Any process or operation which is allowed to progress for some time without review inevitably is affected by creeping obsolescence and change.

With increasing business complexity, the manager may no longer be able to integrate his activities to the common good solely on the basis of his knowledge, experience, perception, and understanding of the need to work with others. In spite of the good performance of common sense, inherent shrewdness, and good business judgment in the past, every method available to optimize the overall performance should be used. Operations Research can help the decision-making process by improving the objectivity and perspective in problem solving.

It should be emphasized that the final responsibility for making decisions will always rest with the executive no matter how much Operations Research has been used in evaluating a particular course of action.

OPERATIONAL VERSUS POLICY DECISIONS.

There are basically two kinds of decisions facing an executive: operating decisions and long-range policy decisions.

Operating decisions are those which are made without the benefit of detailed background study. They often concern problems which arise on the spur of the moment with only a short time available for deliberation. These decisions will continue to be made on the basis of a cursory examination of

the evidence and the backlog of the executive's experience. The localized nature of the problems as well as the relative unimportance of the decisions to the overall operations of the company do not warrant a long and costly Operations Research study.

The long-range decisions concern matters involving previous study, such as important policy questions. The manner in which policy decisions are made will change fundamentally with the introduction of Operations Research.

OBJECTIVE AND QUANTITATIVE ANALYSIS

With the increasing technocracy, more information on the possible courses of action offered to the executive must be analyzed and systematized in a logical pattern so that the potential gains and risks inherent in the various courses can be judged rationally.

Operations Research investigations can take into account the tangible factors involved in major decisions only after the executive has established the operating goals, eliminated inconsistencies in aims, and clarified many issues which will eventually have a bearing on the answer. For example, the inconsistent goals and objectives of production scheduling--minimum production costs, minimum inventory investment, and minimum delay to customers--must first be placed in their proper perspective and combined into a unified and consistent goal.

By taking a factual and objective viewpoint to seek the underlying causes of problems, by studying the effects of more and more variables, Operations Research may make possible better and more effective

decisions showing the alternatives of action, the assumptions underlying each, the consequences of each, and the impact of any decision on other phases of the operation.⁵

Operations Research may improve the decision-making process in five specific ways: more objectivity, fewer guesses and superficial answers, clarification of goals, development of sensitive yardsticks, and evolution of methods for dealing with more complex problems.

The results of an Operations Research investigation may be both tangible and intangible. The tangible results can be either positive or negative. Positive results are those in which there are definite improvements over existing practices. Negative results are those in which the proposed changes under investigation are not found to improve existing practices. However, they can be as good as positive results by giving management assurance on existing programs.

There may be intangible results of such an investigation. The executive may define the company's objectives more sharply. Information gathering causes an awareness of the problem on all levels, stimulating suggestions and new ideas. It can also be used to gain acceptance of programs which otherwise would not have been possible.

Operations Research will make the executive more conscious of the intangibles which could not be incorporated in the study. This will focus his attention on those areas where his judgment is of prime importance--

⁵H. Solow, "Operations Research," Fortune, April, 1951. p. 105.

in appraising the intangible factors and balancing them against the tangible factors of the study.

Although some of the risks involved in a decision will be measured in quantitative terms by Operations Research, few policy decisions will ever be predictable to an extent where no judgment is necessary, at least in the evaluation of certain assumptions made during the investigation. The responsibility for the final decision will remain with management.

BROADER THINKING

Without a formal and objective approach, it is almost impossible to consider all of the ramifications and results of one decision upon the different phases of a business. In most cases, the executive selects some part of the problem, sorts out the factors involved, makes a decision which solves the selected portion of the problem, and is convinced that he has in effect solved the whole problem. It is almost impossible to keep the various alternatives simultaneously in his mind and compare them and their effects upon different factors.

Furthermore, as a result of the process of organizational evolution, many companies are hampered by a narrow outlook resulting from the departmentalization of their thought. Each division in a company has artificial objectives and goals that may be quite inconsistent with maximizing the overall efficiency of the company. Even within a division goals of individual departments can often be incompatible with maximizing the efficiency of that particular division.

Operations Research should help the executive to consider his problems in their entirety and to achieve the most efficient balance among all parts of a modern industrial organization. The nature of an Operations Research investigation normally is so broad that it reaches into many aspects and phases of the overall organization and it is not guided by very narrow and short range objectives covering current and immediate emergencies rather than the optimum solution over a period of time. It attempts to express many variables in quantitative terms and relate them to one overall goal, but without neglecting many individual and specialized problems.⁶

LIMITATIONS OF OPERATIONS RESEARCH

Intangibles and Non-quantitative Data. Operations Research is not a panacea for all business problems. Business problems can not be solved merely with mathematical formulae. Solutions may be derived from using faulty criteria or from evaluating certain data or information out of context. Complex problems can not be confined into a simple and compact problem-solving mathematical formula or model. No model comprehends the universe. It is a presentation of a small and limited aspect on the basis of definite assumptions. In order to exercise sound judgment between alternatives, an executive must understand the structural character and the limitations of the model--what it can and can not do, and what results can be or can not be relied upon.

⁶Morley G. Melden, "Operations Research," Factory Management and Maintenance, October, 1953. p. 113.

Problems which cannot be reduced to an adequate quantitative analysis or in which there are no measurable goals will not be amenable to a solution by Operations Research, and definite recommendations and decisions will be impossible.

Factors which are intangible and cannot be objectively valued cannot be incorporated in the solution. Automation may simplify Operations Research studies because the human variable will be reduced in importance. Insufficient knowledge of human behavior is one of the greatest single limitations of Operations Research.

The accuracy of the results in any Operations Research study is subject to definite limitations due to the inaccuracy of the basic data, the set of assumptions made, and deliberate approximations made in the course of the investigation to reduce the cost and to construct a simpler but less faithful model. The various margins of error, assumptions, and approximations impose definite limitations upon the degree of accuracy achieved and upon the applicability of the results. Furthermore, there is no single measure of effectiveness for the results of a decision which will measure all effects.⁷

Time and Cost. Time will also be a limiting factor since most Operations Research studies require a considerable length of time. The cost of such a study also limits the problems which might be studied. Even if the problem can be solved by Operations Research the expected gains may not always justify

⁷Hurni, op. cit., pp. 11-14.

it. Serious questions arise where the amount of the possible gains can not be predicted. The cost of analysis is a constant limitation in business. There are many problems which can be solved with less effort and less expense through other techniques, in contrast to Operations Research.

POSSIBLE APPLICATIONS TO AIRLINE OPERATIONS

In order to determine whether Operations Research might be applicable to a given business, it is first necessary to:

- a. Recognize problem areas calling for investigation,
- b. Develop new concepts and hypotheses to explain these difficulties from a broad overall standpoint,
- c. Determine whether the problems can be studied by a technique which has proven successful in other similar situations, and,
- d. Plan a program of action to permit evaluation of these concepts and hypotheses.

In applying the above steps to airline operations, it appears that the broad scientific approach of Operations Research might be of considerable value in the areas of schedules and aircraft maintenance.

SCHEDULES

The establishment of schedules is complex and subject to many variables such as competition, traffic potential, traffic demand by hours of the day, by days of the week, and by season of the year, required frequency of service, relative demands between segments, acceptable level of schedule performance versus cost, number of aircraft available, variation of ground times with crew sizes, maintenance requirements, reserve airplane policy, etc.

Among the hypotheses that can be developed for analysis are: the profitability of various schedule patterns can be determined by comparing the net operating profits by flights, it is more profitable to schedule more flights by reducing the reserve airplane coverage even though the number of cancellations would be increased, the overall costs of operating a second fleet of short-range airplanes, the traveling public is more concerned about convenient departure and arrival times than departures on-the-hour or half-hour or a limited time advantage relative to competitors, and most passengers are not unhappy with the schedule performance unless irregularities cause a marked change in their plans without being properly advised.

Complex scheduling problems with many variables have always been difficult to handle. The linear programming theory has been developed recently to plan a complex of interdependent activities in the best possible way. It attempts to select that combination of resources that will maximize the total return. However, the concept is limited by the postulate of linearity, the coefficients relating input and output must be known, and there is no provision for relationships subject to random fluctuations or errors in determination. In spite of these limitations, this method aided in the solution of scheduling buses in Washington, D.C., taking into consideration the routes, traffic, rush periods, number of people at different times, etc. This method might likewise improve airline scheduling practices, superceding intuition, trial and error solutions, and unhappy compromises.

MAINTENANCE

The preventative maintenance required for airplanes between major overhauls can be subdivided and scheduled within broad limitations to meet various requirements. The size of work crews, the airplane time made available for maintenance work, the spare parts assignment, etc., are all subject to change. Even the facilities and their locations can be changed over a period of time. The most marked characteristic of any maintenance work is the marked variability due to the random nature of mechanical irregularities.

Some of the concepts that should be explored in this area are: airplane time is more costly than manhours and special facilities up to a certain point; no routine maintenance should be done during the hours of peak traffic demand during the day; no special project work and fewer overhauls should be done during the peak traffic season; maintenance manpower and facilities should be related to the exposure to mechanical irregularities; more maintenance stations would increase the mechanical reliability; and overlapping turnaround patterns permit greater flexibility than assigned maintenance reserve airplanes.

When the facts involved in a process are too numerous, when the outcomes occur at random or by chance, and the process involved will be repeated a large number of times under similar circumstances, the solution may best be obtained through use of probability theory. The Monte Carlo method, which is based on probability theory and random sampling, may furnish numerical answers to these problems which are too difficult to

solve by rigorous mathematical techniques. Similarly, the queuing theory which is the study of the behavior of waiting lines, backlogs, etc., could be of value in evaluating maintenance station requirements for peaking, balancing the cost of idle airplane time against the cost of idle manpower and facilities.

The program of action to evaluate these concepts and hypotheses would differ from previous studies mainly in the following respects: broader non-departmental approach by a team of 3 or 4 representatives, outside consultant to aid in establishing the methods and techniques developed in other similar situations, more extensive and intensive data, and probably the use of high-speed calculators.

SUMMARY AND CONCLUSIONS

Operations Research is not new. It is simply the further extension of scientific methods in industry. The broader and more objective approach of Operations Research to problems will make possible better policy decisions in complex areas such as airline schedules and aircraft maintenance.