The Status and Application of Operations Research in USA

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General Shin, distinguished guests, ladies & gentlemen, it is indeed a great privilege to be asked to address the Operations Research Society of the Republic of Korea on the occasion of its first meeting. It is particularly meaningful to me because for nearly 20 years while serving in an analysis capacity in Hawaii, I have witnessd the fantastic growth of operations research and decision analysis capabilities in many nations on the western side of the Pacific. The establishment of Korea Operations Research Society is yet another milestone in pacific area operations research progress.

Many of you have dedicated yourselves to the accomplishment of this Goal. You have worked very hard. I am glad, that in a small way, my associates and I have assisted in the growth and development of operational research in the Pacific.

While I have been closely associated with the development of research programs in your armed forces and in your defense department for several years, This is the first opportunity I have had to meet many of you in other segments of your government, industry, and academic communities.

With the establishment of this society, operations research in the Republic of Korea has come of age. I understand that you plan to achieve international recognition of your society by joining the International Federation of Operations Research Societies, on IFORS. As some of you may recall, The International Federation of Operations Research Societies had its last meeting in Tokyo in the Summer of 1975, and plans to meet next in Canada in the summer of 1978.

Your president, general Shin, in his letter of invitation to me, asked me to speak on the subject, "The Status and the Application of Operations Research systems analysis to industries as well as government in the United States." This is a very large order, and in the available time I can only treat the subject in a general manner. But before I do this, I would like to trace the development of Operations Research in the pacific as I have seen it over the years.

In Japan, I worked as an O.R. advisor to the airstaff office beginning in 1957. The Maritime staff and ground staff offices were established office soon after. in 1966, the joint staff and Japan Defense Agency Initiated Operations Research Groups. Industrial operations research capabilities paralled the growth in defense applacations and the Operations Research Society of Japan was established in the MID 1960s.

I have seen your capability here in Korea grow from a gleam in the eye of Brig Gen Kim of the ROK/US operational planning staff to maturity. I understand that each of your services, your JCS MND have O.R. groups. I had the privilege of being a member of an advisory committee to your agency for defense development 5 years ago, and I am pleased to learn that analysis is now an integral part of your defense research and development decision-making process with the establishment of

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your military operations research society, O.R. has become of age in your country. I'm sure that it has also played a role in the fantastic economic growth here in Korea.

The Republic of China on Taiwan established an O.R. capabilitiy in their military establishment 5 years ago, and has made tremendous progress. O.R. is a part of the decision process in their defens military and in each of the services, They have established graduate level educational programs for the purpose of assuring that there will be a continuing supply of trained people, the system analysis society of the Republic of China was established 2 years ago for military and civilian analysts alike. This week they hosted a highly successful interational meeting of operations research in decision-making.

I had worked with the Thailand Defense Department to establish O.R. in their military research and development center for several years. The Asia Institue of Technology in Bangkok has become the focal point of operations research education and advice in Thailand. Approximately 20 young Thai officers were trained in the United States and from the nucleus of an emerging O.R community in Thailand. Three months ago, the Operations Research Society of Thailand was chartered by the government. It will host an International Conference in May 1978.

The youngest member of the Pacific area operations research community is Indonesian. Two years ago, I escorted a group of O.R. specialists to Indonesia to conduct a seminar on the subject of the applications of operations reserach to militray decision-making. We have subsequently assigned a highly qualified O.R. advisor to Indonesia to help them develop a professional staff.

On Monday, Tuesday & Wednesday of this week we held the first regional pacific conference brining together O.R. specialists from Japan, Korea, Taiwan, Thailand, Signapore, and Indonesia. The meeting was sponsored by the Systems Analysis Society of the Republc of China and Tam Kang college and from all points of view, was highly successful. The active participation of 9 reprentatives from your country was particularly noteworthy. The military problems of all countries represented are smiliar.

In the countries of the Pacific operations research applications to industrial and gevernmental problems is following the successful application to military decision problems.

Operations reserach as a recognized part of industrial planning and management in the United States began following its successful application to the problems of military planning and operations in world war II, in 1950, there were a few hundred operations research specialists working in support of hundreds of industrial organizations. A listing of the maior corporations in the United States which employ research staffs reads like the membership directory of the New York stock exchange. Such aerospace giants as general dynamics, Pratt Whitney, Boeing, Lockheed, Transportation Corporations, including United Airlines, TWA, Pan American, Matson Navigation and the State Steamship Lines,; communications conglomerates like western electric, bell laboratories, IT&T, and hundereds of other organizations have operations research groups attached to their corporate headquarters.

The Operations Research Society of American had but a few hundred members when I joined in the early 1950's. Now, the annual meetings of the operations research society are nearly as large as those of the American Bar Association, or the American Medical Association.

What do these operations research specialists do for their respective companies? Why have they been successful? Why is it that industry has found them so valuable and is willing to invest in these

relatively high-priced specialists? certainly, if they had not proven themselves, their ranks would not have grown the way they have grown the way they have. It is obvious that the application of operations research techniques to the problems of business and industry has resulted in improved effiiciency. Lower costs, and higher profits.

There are a number of specialized, quantitative analytical techniques which are valuable to industry. One such technique or area for research, is in marketing analysis.

The problem of marketing are revealed by the type of questions that face the marketing executive. Let us consider a company that sells a low-priced, frequently purchased consumer product throughout the country. Soap powder will serve as an example. Such a product will normally compete with several other brands in any market. Some of these brands will be distributed only in a local area, others will have national distribution; some will bear the producer's brand name, others that of a large distribution chain. Additional competion is encountered from substitute products such a liquid detergents.

The marketing manager's goal is to further the company's profit objectives, both long run and short run.

The main contribution of operations research has been to emphasize the explicit use of mathematical models in marketing research and decision making.

In marketing (as indeed in all fields of science) a model or theory of phenomena deserves attention and utilization to the extent that it is a reasonably useful predictor of observable effects.

Criticisms of market models fall into three classes:

1. Objections that the model excludes some particular features that the individual "knows" to be important.
2. Objections that the model is "too simple" in structure.
3. Objections that the model includes parameters that cannot be measured "Directly."

These criticisms, although interesting are irrelevant. If, in spite of its "serious ommissions," "simplicity," and "indirect measurement," The proposed model prod uces more accurate predictions than a more complex model or any other model for that matter, it S A good model. If on the other hand, the proposed model is a relatively poor predictor, we must formulate a new or modified model that will hopefully achieve the desired quality of accurate prediction.

At the present time the development of useful models is more an art than a science, training is important in the analysis of a proposed model, yet the synthesis of meaningful marketing models is a creative process for the O.R. specialists,

Another technique which is becoming increasingly important to the operations research specialists is that of forecasting. Although there have been many studies published of the problem of planning and scheduling production in the face of known demand, every industry has some planning problems that must be based on a forecast rather than on firm orders. Subjective management predictions of future business can be very useful as estimates of the impact of changes in the economy, marketing strategy, competition, new products, and so on. Such subjective estimtes, however, suffer on two counts, being personal, they are subject to bias and inconsistency among people or over time. Furthermore, since accuracy is limited by the skill, judgment, and experience of the man making the prediction, only a few gross time series (such as total demand by product line) can be predicted. Therefore, considerable effort by O.R. people has been devoted to the development of formal forecasts

techniques. Since the computations can be applied to a very large number of individual products, parts and materials, and the forcasts will be self-consistent.

Forecasts can be computed from the historical and current records of orders placed on the plan sampled weekly in the more dynamic industries and monthly in the more stable industries. It is possible to include management's predictions of future business conditions, or advance orders from customers, as part of the data considered in computing a forecast for any item.

Another major application of operations research is in controlling stock levels. Although many businesses believe that they have an exceptional problem in that everything is produced to order, every business does produce some material to stock. At the very least, raw materials and purchased parts are stocked in advance of actual demand for manufacture. The principal question is how close to finished goods the inventory is maintained. Many manufacturing businesses will manufacture major subassemblies and components to stock, and them assemble to customer specification to make the final product. In addition, many businesses will produce and maintain a stock of spare parts for the maintenance and modification of equipment previsously sold to cusomters. The essence of the stock control problem is the set of decisions

—What to order

—When the order it

—How much to order

—Where to put the material when it is received.

The elementary analysis of these problems frequently studies the question of when to order these items independently of the other questions. The reorder level can be set as the forecast of demand during one production lead time plus safety stock. The safety stock is desigend to protect customer service against uncertainties in the forecast of demand and uncertainties in the production lead time. The standard deviation of forecast errors is routinely measured as part of the forecating computation. The decision problem is what probability to select to represent the average risk of running out of stock. Conceptually, the problem can be formulated as balancing the marginal cost of carrying an additional quantity of stock against the marginal income from improvement in customer service. A variety of cost models has been studied. In many manufacturing industries it is difficult, it not impossi ble, to obtain realistic data to represent the cost of depleting the stock level problem presents interesting challenges to the analyst.

Production scheduling and sequencing problems are also treated by the industrial analyst. The manufacturing process usually consists of a number of stages such as foundry, machine shop, sheet metal, assembly, and test.

It is typical to think of the processes being in a fixed sequence for manufacturing a product. One area in which apparently very little operations research has been published, and in which great payouts might be expected is the exploitation of alternative sequences for a given product. Obviously a hole must be drilled before it can be tapped and countersunk. If the drill presses are overloaded, however, it might be possible to send work to the grinders first and then come back to drill presses at a later time. A few companies have done a conscientious job of showing alternative routines or routings on the standard sheet. This flexibility makes for a considerable increase in the efficiency of scheduling.

The scheduling problem is essentially one of monitoring the queue or waiting time for the jobs

ahead of any work station. Much attention has been devoted to a variety of formal rules for selecting which item to put at the head of the waiting line. One of the most effective rules that has been tried so far is the "minimum slack time per operation" rule, every job has a due date when it should be through the last operation. The scheduled assembly time for a larger component, or it may be the promised date for delivery to a customer. The operating time is the sum of all the setup and running times on each operation between the present stage and the final operation on the item. If the item is made in a large batch and there is lap-phasing, a nominal process time may be stated when the first piece will be delivered to the next stage. If the move times between successive operations tend to have considerably different lengths, move times should be considered as part of the operation. If it takes about the same time to move between any pair of operations, move times need not be considered. The slack time remaining for the job is the total time between now and the required finish date minus the sum of all these operation times. The slack time can be computed for each item in the queue in front of a given operation. The jobs in the queue are then sequenced by this minimum slack time per operation; The one having the shortest available time is run first. The theoretical treatment of scheduling and sequencing problems poses a challenge to the analyst.

Problems relating to purchasing are also of interest to the analyst. Often, the material from which the product is manufactured must be purchased from external sources. It may be in the form of raw materials or semifinished parts and products. The purchasing problem is similar to the stock control problem operations research has been quite useful in developing rules for deciding when to order more material form outside sources and how much to order at a time.

Let us now look at a few examples of how operations research has benefited industry. A classic case is that of seabrook farms. seabrook farms is a giant farming enterprise in Southern New Jersey, It is a completely integrated industry vegetables are raised, processed, quick-frozen and stored at the farm and, from there, are distributed to points along the eastern seaboard. The seabrook farms trucks are constantly traveling between the warehouse and such places as boston, New york, philadelphia, Washington, Richmond, Charlotte, Miami, and other eastern cities, carryingmillions of packages of frozen vegetables to local dealders. From the time the vegetable is planted nearly to the time that it is carried to the dinner table, seabrook farms controls all aspects of the operation. This large undertaking, provides excellent opportunities for operations research. Seabrook farms had seven thousand acres of peas; These had been planted during the period from early March through the first part of April, and all were approaching maturity late in May. The problem was to get these peas out of the fields and into the plant at the stage when they were just ready for freezing.

The managers needed to know, "When would the harvest start?" in what order would the fields be harvested? how could the work force keep up with the rate of the maturing of the crop? They needed to have some method for predicting when a field would be ready to harvest. Their means for determining the stage of crop maturity were rather primitive, for example, a fild man would shell out some peas by hand and squeeze them to see if the felt "Right" or he would toss them up and let them drop on the hood of an automobile, listening to see how they rattled. Usually, however, the questions of whether or not the crop was ready was more or less academic: The harvest would typically begin a little early so that work would could get off to a good start, and would not end before some of the peas had alredy grown to over-ripeness.

When the peas began to mature at a rapid rate, the mangers tried to speed up the rate of harvest.

If they were not able to keep pace by working twleve hours a day, they were prepared to work twenty-four, with double work crews spelling each other around the clock, and with giant floodlights illuminating the field by night. Even this stepped-up activity, however, did not make it possible to harvest all the peas at the optimum time. During the harvest, there would be a period when the peas were just right: those harvested a little early were too young; and those which formed the backlog were too old.

The rapid harvesting itself introduced some additional problems. Peas tended to pile up at the factory, and the freezer capacity was overtaxed, with the result that many of the good peas had to be canned rather than frozen. Since canned peas are not so profitable as forzen peas, this represented an economic loss to the farm.

The analysis were able to develop a system to optimize the inter-related variables.

Sweet corn, snap beans, lima beans, and spinach fitted into the master scheme. The growth of spinach can be described in terms of the growth of peas, the yardstick of the climatic calendar. similarly, the nodes on a pea vine are an adequate, in fact, a good means for describing the rate of development of sweet corn, or lima beans. In the master plan, therefore, it can be arranged that, on the day following the end of the pea harvest, a field of snap beans will be ready for harvesting; that, on the day after the snap beans have all been gathered, the first field of corn will be ready, and so on through the crop year.

The data necessary for such scheduling were reduced to a simple slide rule which translates the civil calendar into a climatic calendar, which tells when to plant and harvest each crop to achieve optimum results.

The chemical and pharmaceutical industries are industries in which there must be a continuous balancing of demand, inventory, and output. production plant size and location are also important variables. Teams of operations research specilalists applying their skills to complex production scheduling and process optimization problems, inventory control and distribution problems, have reduced costs and increase a profits in this important area.

In the late 1950's, I was closely assocaited with the Matson Navigation company which had a new small four-man operations research group. The group looked for useful things to do. They studied the time honored system of loading and unlodaing ships through the hatches from the holds. Being analysts, and not seamen or long shoremen, they reasoned that there must be an easier, more efficient way. They developed a concept for preloading the cargo into large boxes or containers which could then be loaded, and unloaded from the ship in short order. Their study was sufficiently persuasive, that Matson committed itself to a multi-million dollar investment program, which has paid off handsomely. Containerization has now revolutionized the entire steamship transportation industry.

In many ways, applying operations research techniques to problems of business or industry is more satisfying professionally then, say peacetime military operations research, because the results are so apparent. One can see the improvements for which he is responsible and measure the magnitude of the improvent by the increase in the profits. The military analyst, on the other hand, frequently must wait until an opportunity to test his results in a combat situation arises.

While operations research applications to industry have grown rapidly in the United States, there is still much to be done. The almost universal ability of high speed computers are making possible mathematical simulations of the most complex problems which fall the decision maker. Management

controls and managment information systems are being developed which take much of the guess work out of the decision process. Forcasting is one of the fastest growing sub-disciplines of operations research and will continue to receive broader application, In summary, the application of operations research to industry in the United States has come a long way, but still has a bright and promising future.

I would like to mention briefly some of the united states government, non military uses and applications of operations research, in government, probably even more than in industry, the resources are always less then we need to accomplish the good and useful things we would like to accomplish. therefore, we must choose those things which contribute most to our national objectives.

In industry, as we had mentioned earlier, profits provide the feedback on the quality of decisions. This measure of effectivenss is absent in government operations, however, leaving the results of the application of operations research somewhat more obscure.

Most major departments and bureaus in the United States currently have operations research support. I will touch on a few:

The post office department is a large and complex organization, consisting of a nation-wide network of facilities and services. Dr. Tuan, who is present with me today, worked as a private operations research consulant in support of the post office.

Another complex regulatory agency, to which the principles of operations research apply, is our federal communications agency which has management authority over a complex, nationwide network of communications frequencies and facilities.

Other activities include the bureau of the budget, the bureau of the census, federal aviation agency, health education and welfare, bureau of mines, and many others.

The extent of operations research use in the United States government can also be measured from the wide range of reports to be given in the 1976 joint national meeting of the Operations Research Society of American and the Institute of Management Sciences to be held in Miami next month. some of the examples include the technical session topics that are devoted to operations research in the government and the public sectors are as follows:

—Operations research application in primary care delivery
—Operations research in education
—Operations planning for campuses
—Judical systems design
—Operations research in criminology
—Operations research in law enforcement
—Modeling for highway traffic research
—Analysis of transportation networks
—OR/MS in the railroad industry
—Travel and tourism
—Environmental problems
—Energy resource management
—M.S. Applications in the electric power industry
—Energy modeling
—Water resource management

—OR/MS and governmental regulatory agencies

—Decision models in political systems

—Application of simulation in the public sector

—Research in public administration

—Operations research in public planning

—Productivity in urban services

The growth and development of operations research in the United States governmental operations have paralleled the growth in industrial applications, and in many ways the problems are smiliar.

I'm afraid that in this short period I have only skimmed part of the surface of a very extensive subject.

Is there any way that I can be of service to you in answering your specific questions, I invite you to write me and I will attempt to assist you.

I thank you for inviting me to be your guest and wish the Korean Operations Research Society a bright and successfful future.