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A Personal Perspective on Operations Research

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Abstract

In this presentation, I will try to sketch the present status of Operations Research and Management Science which I have gleaned from my own experience. It is said in Japan that OR/MS was an excellent tool for managers up to the early 70's, but that in recent years it has not been utilized so widely. In addition, there seems to be a big gap between academics and business circles regarding the use of OR/MS and the gap is becoming bigger. Many people see this gap as a crisis for OR/MS.

Firstly, I will explain several causes of this gap, emphasizing the importance of tight cooperation between models, algorithms and applications which, I think, constitute a kind of *troika* in OR/MS. Then I will briefly survey models, algorithms and applications of OR/MS. Finally, after emphasizing the role of optimization, I will talk about my personal view on the future development of OR/MS.

Keywords: OR/MS, status, model, algorithm, application, optimization, perspective on OR

1 Introduction

I have been engaged in the study and teaching of operations research and management science for nearly thirty years. In this period, OR has achieved significant progress but this has not been straightforward.

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In fact, it is said in Japan that OR/MS was an excellent tool for managers up to the early 70's, but that in recent years it has not been utilized so widely. In addition, there seems to be a big gap in attitude between academics and business circles regarding the use of OR/MS and the gap is becoming bigger.

In the second part of my talk, I will discuss the causes of this gap. Then, I will give a summary of models, algorithms and applications of OR/MS. I will then emphasize the role of optimization as the mathematics of the century and lastly I will discuss the future prospects for OR/MS.

2 Real *vs.* Hypothetical Situations in OR/MS

Like other practical sciences, OR/MS relates to both the real and the imaginary worlds, where 'real' means practical problems and 'imaginary' means their models. Within the imaginary world, we have freedom in expressing and treating the actual problems, and the solutions obtained in the imaginary world may be successfully applied to the practical problems. For example, the OR models such as LP, PERT and so forth, are results of this relationship and practitioners can obtain useful information from the solutions. It should be noted that this kind of relationship had not been clearly investigated until fifty years ago, when OR/MS came into existence. They are the creations of OR/MS. The model-building process is crucial to the success of OR/MS.

The duality relation between the real and the imaginary worlds is, to some extent, common to all sciences and technologies. We have seen many instances of people in the other fields applying methodologies developed in our field. It may safely be said that we have been at the forefront of a variety of valuable models and methods. Actually, LP, PERT and simulation are widely being used by people who are not conscious of the fact that these methods were developed by OR/MS. If there was a 'balance of trade' between academic societies, we are exporting more than importing, and so our balance is firmly in the black. Although these exports bring us no real world profits, we have at least gained the respect of others.

Again, I would like to emphasize the dual characteristics of OR/MS, i.e., the real and the imaginary. If the relationship between the two becomes distant, it means that the practitioners no longer need the solutions from the academics and/or that the academics stop dealing with applied problems. When OR/MS was in its infancy, such estrangement was not allowed, because

during the Second World War, OR dealt with real problems upon which fate of organizations (nations, departments etc.) depended. After the War, the '50s was a decade of rapid advance in OR/MS. This trend continued during '60s. Many useful OR methods were developed during this period and they constitute the main repertory of OR/MS today.

However, in the '70s, with the first oil crisis in 1973 as a turning point, there came the criticisms that "OR is useless for managers," or "OR is a kind of hobby of mathematicians", which suggest a potentially large gap in perception between practitioners and academics. OR/MS could not provide effective solutions to the oil crisis and to the resulting problems. During the period of 1970-1990, Japan experienced such significant social and economic events as the boom for remodeling the Japanese archipelago (1972−), led by the ex-Prime Minister Kakuei Tanaka, the second oil crisis (1979), the bubble economy (1986−1989) and the collapse of the bubble (1990), which is still under way. In particular, during the boom economy of 1986-1989, enterprises could achieve higher profits by speculation, such as investment in land or financial operations, than by sophisticated methods such as OR/MS. After the '70s, the departments of OR in enterprises fell in number and scale and some of them were absorbed into information system divisions.

One of the causes of this retreat was academic trends. At the beginning of OR/MS, most problems were case-oriented. Since then, a movement to integrate such cases into a unified theory has begun, reflecting the common characteristics of sciences. What are the merits of such integration? Firstly, we can get a deeper understanding of the actual phenomena. A method developed for solving some problems can be successfully applied to other problems. For example, a travelling salesman problem solution can also be applied to machine-job scheduling problems. Through this type of unification, we can find new problems and their solution methods from a more sophisticated point of view. This should result in progress in this science. Until the '60s, this kind of research was carried out extensively with successful applications. However, thereafter there arose a tendency in academics to aim for an overall theoretical standpoint, independently of practitioners, from which they could construct a unifying theory.

Theories based on hypothetical situations were the stepping stones to a unified theory. Because of the *idée fixe* which became prevalent in the academic worlds, these hypotheses took the place of the real world for many academics and the resulting theories were based on poorly certified assump-

tions. From the pinnacle of these theories, the real world is no longer clearly visible. The distance between practitioners and academics has become so great that they cannot understand each other as they did before. This degraded the evaluation of OR/MS in business circles. The teaching of OR/MS in universities has accelerated this movement, since they focus on pulling students up to the top level of research by the shortest route and in the minimum time. Thus, the application side becomes a secondary matter in the teaching of OR/MS.

The above mentioned developments have occurred since around 1970. In many journals on OR/MS, there appeared articles consisting of theory for theory's sake. However, I am still optimistic about this tendency, because the strength of theories in OR/MS depends directly on their origins in practice.

3 Troika

As I mentioned previously, applications (practices) and models are key factors in OR/MS and we need algorithms for solving models. Thus, models, algorithms and applications constitute a *troika*. We have to roll the wheel of the troika smoothly in order to develop successful OR.

We have accumulated a significant stock of models, algorithms and applications. I will deal with some typical titles; this list is not exhaustive.

Models

Linear Programming	*Queue*	*PERT*
Nonlinear Programming	*Graph/Network*	*Simulation*
Dynamic Programming	*Markov*	*Forecasting*
Stochastic Programming	*Logistics*	*Gravity*
Transportation	*Facilities Planning*	*Marketing*
Inventory	*Scheduling*	*Game*
Finance	*Reliability*	*System Dynamics*
Applied Probability/Statistics	*Multiple Criteria*	*AHP*
Computational Geometry	*DEA*	*Neural Network*
Fuzzy		

Algorithms

Simplex Method	*Interior Point Method*	*Goal Programming*
Combinatorial and ILP	*Monte Carlo Method*	*RegressionAnalysis*
TimeSeriesAnalysis	*SamplingMethod*	*Simulated Annealing*
Neuro – Computing	*Tabu Search*	*Portfolio*
Voronoi Diagram	*Branch&Bound*	*GeneticAlgorithms*

Applications

Advertising	*Agriculture*	*Airline*
Automation	*Banking*	*Battle*
Capital Budgeting	*Conflict Resolution*	*Cost Benefit Analysis*
Criminal Studies	*Decision Making*	*Defense Analysis*
Electric Power	*Emergency Services*	*Experts Systems*
Environments	*Finance*	*Fire Model*
Flexible Manufacturing	*Forecasting*	*Geographic Inf. Systems*
Health Care Systems	*Higher Education*	*Information Systems*
Industry	*Inventory*	*Libraries*
Maintenance	*Manpower*	*Manufacturing*
Marketing	*Material Handling*	*Medical Practice*
Military	*Natural Gas*	*Natural Resources*
Office Automation	*Pattern Recognition*	*Politics*
Public Policy Analysis	*Railroad*	*Recreation&Sports*
Research&Development	*Retailing*	*Space Program*
Telecommunications	*Traffic Analysis*	*Transportation*
Urban System	*Vehicle Routing*	*Water resources*
Yield Management		

We can see that applications cover both private and public sectors including the primary, secondary and tertiary industries.

The broad range of applications suggests that OR/MS is a fundamental science, since the more basic the science, the wider the application areas are. (See Gass and Harris [3] for details.)

4 Optimization: the Mathematics of the Century

It may safely be said that the history of optimization has been parallel to that of OR/MS. In recent years, optimization has been the method of choice in many areas. We can see the background of this movement in the following way:

1. In competitive environments, efficient planning is required.
   (Logistics)
2. Management has become more cost-conscious.
   (Transportation)
3. The finiteness of resources is a world-wide issue in modern society.
   (Energy)
4. Choices from alternatives are crucial for successful management.
   (Product-mix, Finance)
5. Environmental problems are important global issues.
   (Pollution)
6. Due to the scaling up of facilities and automation, efficient planning and operation is needed.
   (Plant Operation)
7. Finer analyses and designs are required in many areas.
   (Medical Diagnoses, Design of VLSI)

Historically, each epoch experiences the mathematics of that epoch. For example, the Greek era had Euclidian Geometry and the industrial society after the Industrial Revolution developed Differential/Integral Calculus and Linear Algebra. After Toffler [6], it may be said that these mathematics correspond to the first and the second wave (the invention of machines and the energy revolution). Now, we are experiencing the third wave of industrialization (the information society). This era has created its own mathematics: information mathematics, among which optimization has a crucial role. Optimization began in 1947 when the simplex method of linear programming

was invented by Dantzig [2]. Since then, we have developed many models, algorithms and applications for optimization, as we saw in the preceding section. In 1984, an important advance occurred in optimization, i.e. Karmarkar's interior point method for linear programming ([4]). Motivated by this method, it was found that the Newton's method for solving nonlinear equations can be applied to solve the Karush-Kuhn-Tucker condition of general nonlinear optimization problems. Nonlinear optimization problems can be handled in a unified approach and we have the means to solve very large LP problems by the interior point method. This has greatly enhanced the power of optimization. By the end of this century, we will have made even more progress in algorithms and applications of nonlinear programming and combinatorial optimization.

To our regret, these developments have not been fully appreciated by Mathematical Societies. Subjects related to optimization are worthy of consideration in the higher/middle education mathematics curriculum. Established societies are usually closed and not willing to open the door to newcomers. We should help such societies understand our accomplishments more completely through our professional organizations, such as APORS and IFORS.

5 Future Prospects

As I said before, we have an excellent repertory of OR/MS. However, this stock is not sufficient for us to survive as a profession in such a competitive society. In the last several years, we have seen the storm of restructuring which is attacking the main industries worldwide. Referring to the computer industry, the main-framers are under perpetual pressure to downsize. We should carefully plan our course, taking into account these revolutionary changes in the business world. Our achievements in the past have been significant and we should continue to pursue the same objectives, particularly in the academic field.

With this in mind, I would now like to present a personal perspective of OR/MS in the future.

5.1 From Organizational to Individual

Most modern industries have been built upon the inventions of individuals. For example, Edison is the father of the electric industry and Shockley's transistor led the way to the electronic industry. However, the bigger an organization becomes, the more bureaucratic it is likely to be. Thus, organizational behavior and decision making tend to suppress individual creativity in the organization. We can see an example in the case of the reaction of main-frame computer makers when the wave of down-sizing began. Some of them were slow at coping with the tide and were eventually submerged. In this time of rapid change, we need the creative, humanistic activities of individuals. It is time to return our focus to the individual rather than the organization. We have to seek and cultivate our own region of existence through the power of individuals. Organizations should allow their members to develop their ability and act positively to commercialize the resulting products. OR/MS is no exception to this, and it, too, needs the creative abilities of talented individuals.

5.2 OR for Performance Evaluation

In view of the present managerial environment and the future outlook, it has become a crucial matter for every organization to evaluate the efficiency of its performance properly. This is especially true for public sector enterprises such as schools, hospitals, health care, transportation and so forth, since they are increasing both in number and scale, their role is growing and they are apt to be less efficiency-minded. They usually have multiple-criteria as the guiding principle of behavior. We can see them as a transformer from multiple-inputs to multiple-outputs. DEA (Data Envelopment Analysis) by Charnes and Cooper ([1], [7]) is an innovative method for evaluating their relative efficiency in multi-criteria environments.

DEA utilizes fractional programming to evaluate the relative efficiency of each organization by the ratio scale of multiple-inputs *vs.* outputs. Since DEA stems from quite a different concept to previous methods e.g. statistical regression analysis, it may be said that DEA has been arousing a Copernican change of view in the management science community. I hope that DEA will be applied to many real situations, deepen its knowledge from such experiences and be an appropriate method of choice for OR/MS.

5.3 From Tangible to Intangible

There is a prejudice that OR/MS deals mainly with quantitative rather than qualitative data. OR methods for intangible situations, especially for decision making purposes, have been necessary for many practitioners for a long time. The AHP (Analytic Hierarchy Process) developed by Saaty [5] is a breakthrough for this purpose. Although there have been discussions on the effectiveness of AHP, e.g. the lack of axioms and the rank reversal phenomena, many practitioners are using AHP as a useful decision-making tool. This is because the hierarchy structure and the pairwise comparisons do naturally correspond to the behavior of decision makers and AHP succeeded in formalizing this process in a unified manner. It is worth noting that AHP is often being used by people outside the OR/MS community, for example as a part of an Expert System, planning of new products, portfolio selection and so forth. People can get valuable information from the practice of AHP in proportion to their experience and knowledge of the problems concerned. Thus, AHP could be used as a means for constructing a man-machine system involving experts and is fitted for group decision making.

5.4 Back to Basics with Innovated Media

There were several classical basic OR problems at the outset of OR/MS. One of them is OR for retailing, which can be seen as the third phase in the flow of goods, following production and logistics. OR/MS has been used in retailing for some time, typical examples being the "newsboy problem" (a classical inventory problem) and the "traveling salesman problem", one of the origins of combinatorial optimization.

In recent consumer-oriented environments, OR for retailing has become an important current topic. In the mid 1980's, the popularity of the "Point of Sales" (POS) information system increased. This system uses a photo-electronic cash register to scan the bar code on the commodities, transforming the information on retail sales into the host computer on a real-time basis. Thus, a store has access to a massive amount of consumer information from its database. This system has two kinds of benefits. Firstly, there are so-called *hard benefits*, e.g. the speeding up of cash register operations, the increased accuracy in accounting, and manpower reduction. Such benefits help to offset the costs of the system to some extent. The second type of

benefits can be termed *soft benefits.* These are gained from the processing and analysis of the POS data using appropriate software methodologies. Using such software efficiently can result in large increases in profits and the role of OR/MS in this regard is remarkable. The application areas include prediction of the number of consumers visiting a store, classification of goods by sales volume, inventory control and analysis of movement of customers. (See Tone [8] for details.)

A flood of POS data is being obtained from POS registers daily and in the worst case will turn out a mass of useless information. It is quite urgent and important for us to select and create valuable information from POS data. If successful, the flood will turn out to be a multipurpose reservoir. The current state of the art is far behind the ideal. We lack methods and software for realizing the soft benefits. We will be able to build-up a truly valuable management information system only when these problems are solved.

5.5 Efficient Algorithms in the Background

Nowadays, we have several spreadsheet type software packages that make it easy to add up selected items from the data or to display the data visually on the screen. For example, we have software packages for plant scheduling. They can be utilized as a kind of model building language with high potential applicability. They emancipate schedulers from the burden of tedious and time-consuming paperwork and are good at quick response and visual display on demand. If OR methodologies for scheduling were incorporated into them, we could expect more effective plant scheduling with less lost time and less opportunity loss. For this implementation, tight cooperation between software engineers and operations researchers would be required.

I hope that many model building languages with visual functions will be developed in diverse areas and that OR methodologies will be embedded in them. This will result in a highly efficient system and contribute to an enhanced reputation for OR.

6 Summary

In this presentation, I have given my personal view on the prospects for the future development of OR/MS, after analyzing its past and present status.

Although we have a vast and significant OR repertory, this is not, by itself, sufficient for us to advance as a profession in the future. We should develop our methodologies in close cooperation with the multi-media and software engineering fields.

I believe that our future will be bright if we endeavour to innovate OR/MS along the lines mentioned above. Lastly, let me cite the Angel's chorus from Part Two of Goethe's Faust;

Wer immer strebend sich bemüht,
den können wir erlösen.

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