

オペレーションズ・リサーチの史的展開： 企業経営と技術革新

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Evolution of Operations Research: Business Management and Technological Innovation

by

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Abstract

As the computer technology advances, the theories of operations research are actually applied to the problems that companies face. In the business field, it is called “Management Science”, and it is also named “Systems Analysis” in the field of system engineering. In this paper, we will show that the techniques of operations research has actually used in many companies as computer technology has advanced.

§1. Introduction.

Operations research, also known as operational research, is an interdisciplinary mathematical science that focuses on the effective use of technology by companies. We can get optimal solutions to complex decision making problems by operations research method that employs techniques from such mathematical sciences as statistical analysis, mathematical modeling, and mathematical optimization. Since the operations research emphasizes practical applications and human-technology interaction, operations research has overlap with other disciplines, namely industrial engineering and management science. At the same time, it utilizes a wide range of problem-solving

techniques and methods such as probability theory, queuing theory, simplex method, game theory, graph theory, decision analysis, mathematical modeling, network flow analysis, dynamic systems theory, and simulation. (see, e.g., [26] and [27]) Due to the computational nature of these theories and analyses, it strongly relies upon computer science. (see, e.g., [17])

In this paper, we will study the historical development of operations research and its related disciplines. Then we will show real world applications of the operations research techniques and how effective these techniques are.

§2. Historical Development.

In this section we will provide a historical perspective on the development of the field of operations research and briefly outline the development of operations research and management science. Operations research can trace its beginnings to military operations

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research formed at the Bawdsey Research Station in Great Britain in 1937 during World War II. In 1939 the British OR groups consisted of a team of people from different fields of science, mathematics, and the military, brought together to find solutions to military-related problems. The “Blackett’s circus” is one of the most famous of the groups. Its leader was Nobel laureate P. M. S. Blackett of the University of Manchester and his fellow researchers were a former naval officer, three physiologists, an astrophysicist, two mathematical physicists, a general physicist, two mathematicians, an army officer, and a surveyor. (see [13] [28]) Blackett’s group made significant contributions in improving Britain’s early-warning radar system. Its success led to the establishment of the OR groups in the U.S. Air Force and the U.S. Navy. After World War II the U.S. Army, the U.S. Air Force, and U.S. Navy set up various agencies such as the Navy’s Operations Evaluation Group at MIT and the Project RAND established by the Air Force, to continue research of military problems, using knowledge and techniques of operations research. At the same time, many consulting firms were established to utilize these techniques to apply to business problems. In the early 1950’s, solving management problems with the use of quantitative techniques became known as management science. The objective of management science is solving the decision making problems that face business, industry, and government by developing mathematical models based upon operations research. Since then, operations research techniques has expanded into a wide range of field, ranging from petrochemicals to airlines, fast-food chains, finance, transportation, and government.

Until the late 1960’s, the lectures for both management science and operations research at the many universities in the U.S. and Japan were mostly theoretical. In the late 1970’s the emphasis in both operations research and management science has shifted away from strictly mathematical to mostly computer solutions because of computer and information technology. However,

solving a simple linear programming problem or regression model by computers took about 5 hours in those days.

In the 1980’s many computer software packages such as DSM and QM for windows were developed. Then the lectures in the universities started to use these computer software packages, and also many firms utilized them for their decision makings.

§3. Related Disciplines.

As we mentioned earlier, operations research has overlap with other disciplines, such as system analysis in industrial (system) engineering and management science. Management science is also utilizes other academic disciplines such as business administration, economics, sociology, and psychology. By utilizing knowledge in management science, people can analyze problems of firms and build mathematical models to develop solutions. Of course, in order to achieve a goal, knowledge in operations research, computer programming, and database management is required. Another field that is closely related to operations research is systems analysis that helps decision makers to identify a better course of action and make a better decision that he might otherwise have made. When a computer-based information system is developed, there are a number of different approaches to systems analysis. Usually systems analysis consists of 5 phases, namely scope definition, problem analysis, requirements analysis, logical design, and decision analysis. At the same time, there are many types of systems analysis such as accident analysis, spiral model, business analysis, morphological analysis, waterfall model, and software prototyping. The major subdisciplines in modern operations research are computing and information technologies, decision analysis, financial engineering, service sciences and supply chain management.

§4. Real World Applications.

In this section, we will show real world applications of

operations research and management science. We describe how a company, organization, or agency uses the particular operations research and management science technique. Real world applications of management science are abundant. Most of these applications are presented in a scholarly journal called *Interfaces* (An International Journal of the Institute for Operations Research and Management Sciences). (see, e.g., [4], [6-9], [11-12], [16-19], [21], and [24]) Application works in operations research, like other engineering and economics' disciplines, attempt to use models in order to make practical impacts on real-world problems.

First, we will explain “a system based on mixed-integer linear programming and expert systems to improve customer service” developed by Soquimich, a Chilean fertilizer manufacturer. (see [1]) The company is the leading producer and distributor of fertilizers in the world with revenues of about a half of billion U.S. dollars, and does the business in more than 80 countries. It produces four main special fertilizers and more than 200 fertilizer blends according the needs of its customers. The customers want the company to recommend optimal fertilizer blends for their crop at the lowest possible cost, providing the information about previous crop yields and their target yields. Then the company obtains soil samples and analyzes them in its laboratory to find out the soil requirements for nutrients such as nitrogen, phosphorus, potassium, boron, magnesium, sulfur, and zinc. Given these soil requirements, an optimal fertilizer blend will be determined by using a linear programming model that minimizes the farmer's production costs with constraints for the nutrient quantities required by the soil. It can provide the company with accurate, quick, low-cost estimates to the customers. Compared it with the time-consuming manual procedure conducted by the experts in the company previously undertaken, it helps the company gain new customers and increase its market share.

The next example is project management of the 2002 Winter Olympic Game in Salt Lake City. (see [14]) It

was a large project which encompassed a 5-year planning period and took 1.9 billion U.S. dollars cost. Project management had been used for large construction-related projects in previous Olympic Games. However, by the Salt Lake Organizing Committee (SLOC) classic project management methods were used at all levels. As a result, the SLOC could make 100 million U.S. dollars surplus instead of a projected 400 million U.S. dollars deficit. In 1998 the SLOC employed a Primavera project management software system, awarded 3,780 contracts valued at about 1 billion U.S. dollars, and issued 7,000 purchase orders. To complete the development of the project and work plans took 1 year, by employing an “Executive Roadmap” to keep executives and managers apprised of progress. The Office of Operations Planning and Management paid a detailed attention to the project schedule, so the SLOC was able to know when the plan was off schedule and where to apply additional resources. By all measures the 2002 Winter Olympic Games were a great success because of project management in large part.

The third example is “The Analytical Hierarchy Process at Dar Al-Hekma, Saudi Arabia”. (see [5]) All universities and colleges in Saudi Arabia were public before 1999. However, there was an increase in demand for higher education, so the Ministry of Higher Education in Saudi Arabia allowed nonprofit, private colleges in 1999. Under this new educational policy, Dar Al-Hekma College for women was founded in Jeddah, which offers degrees in business information systems, interior design, and special education. However, it faced the lack of qualified female faculties. Then, the Ministry of Higher Education provided the college with nine scholarships to send women to the U.S. and the U.K. for graduate studies to alleviate the problem. In order to select nine candidates, a committee was established. The committee used the analytical hierarchy process (AHP) to select the scholarship candidates. A qualitative set and a quantitative set of criteria were determined. The former set included

subcriteria for personality, work experience, and other information, while the latter set included subcriteria for language and previous academic achievement. Various measures such as essays, work experience, GPA, and TOEFL scores were taken to rank candidates in each category. The AHP model was successful in reducing subjectivity and ensuring fairness in the selection process, and provided a systematic framework for the committee members' decision making, and it saved time and removed potential personal and political conflicts from the selecting process.

The last example is "Reducing Perceived Waiting Time at Bank of America". (see [29]) Bank of America found out that a gap develops between the actual waiting time and the customer's perceived waiting time when a customer waits for teller service for more than approximately 3 minutes in line. For instance, the customers feel like they have been waiting for 2 minutes if they wait for 2 minutes. However, they feel like 10 minutes when they have been waiting for 5 minutes. At the same time, Bank of America learned that waiting time has a direct relationship to customer satisfaction. Moreover, the bank knew that time would seem to pass more quickly if the customers were distracted with non-boring activities according to the psychological studies. Therefore, the bank undertook an experiment to examine if the customer's perceived waiting time could be reduced when the bank placed television sets above the tellers in a bank branch lobby to entertain customers waiting in line. Thus, the bank installed television sets tuned to CNN in a bank branch and checked actual versus perceived waiting times. As a result, comparing with a bank without television sets, the amount of waiting time customers overestimated dropped from 32% to 15%. This experimental results indicated that the projected reductions in perceived waiting times would result in a 5.9-point increase in the customer satisfaction index, and every one-point improvement in the index results in \$1.40 in increased annual revenue per household customer. Thus, a bank branch with 10,000 household customers could expect an increase in annual revenue of \$82,600 with cost of about \$10,000 for installing television sets.

Other than the above examples, there are many companies that utilize operations research and management science techniques. For example, banks use expert system to refine credit-scoring models that assess the credit worthiness of loan and credit card applicants. Insurance companies also use another type of expert system. They have their own scoring systems to evaluate applicants for policies and determine whether they should be accepted.

§5. Concluding Remarks.

We have studied a historical development of operations research and some related disciplines such as management science and system engineering. Then, we provide real world applications, and show how mixed-integer linear programming, project management, analytical hierarchy process of multicriteria decision making, and single-server waiting line system work for the institutions' objectives.

As we have studied in this paper, advancement in such academic disciplines as computer programming, statistics, and database management has made operations research and/or management science the most indispensable to organizations such as government, companies, hospital, and universities, and the use of modeling techniques has been increasing rapidly because of these academic disciplines.

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