Operational Research

Origins, Methods, and Applications

"*My business card says Data Mining, Performance Measures, and Decision Support. Those are my attempts to translate operations research into English.*"

– *An independent OR consultant*

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The origins of Operational Research

Operational Research (OR) is a discipline whose origins can be traced back to the second half of the 20th century that uses mathematical and statistical models to solve complex problems in the search for an optimal solution that enables the best decision making.

With a wide application field, OR currently covers several types of knowledge and techniques, such as Linear and Non-Linear Programming, Dynamic Programming, Simulation, Game Theory, Forecasting, Project Management, etc.

Identifying and making the best decision that would lead to victory has always been a constant concern of those who waged war. To achieve this, the military often turned to knowledge holders at every historic moment.

That is why many experts consider that OR dates from the 3rd century BC, when, during the Second Punic War, Syracuse, besieged by the Romans, defended themselves using the solution proposed by Archimedes, with a system of mirrors that guided sunlight, thus managing to set fire to enemy ships.

In 1503, Leonardo da Vinci participated as an engineer in the war that opposed Pisa to Florence, putting his knowledge of building ships and other vehicles, cannons, catapults and other war machines at the service of this city.

OR has always relied on mathematics, having had a huge impact on the works that, in the 17th and 17th centuries, Newton, Leibniz, Bernoulli and Lagrange developed works related to obtaining maximum and minimum conditions conditioned to certain functions.

At the same time, the Fourier outlined the methods of the current Linear Programming and, in the last years of the 18th century, Monge established the precedents of the Graphic Method from his studies of descriptive geometry.

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As most relevant examples of the work carried out by these groups of scientists, in the United Kingdom, in 1939, mention should be made of the increase in the efficiency of radars and the optimal performance of the British air defense system, fundamental to the victory at the Battle of England, as well as, in the United States of America, in 1942, the use of mathematical models in the movement of merchant ships to break the blockade that the German Navy imposed on the United Kingdom, taking into account restrictions and real conditions such as the cargo to be carried, the maximum speed and the necessary fuel.

At the end of the war, encouraged by the success of the OR at the military level, the business world, namely the industrial sector, gradually began to take an interest in this discipline.

The OR teams had shown, in the course of the previous conflict, that they were able to solve complex problems, involving many variables, using methods that had allowed to obtain greater efficiency in the use of armament and valuable savings in human and material lives, being susceptible of application in the civil sphere.
The problems were basically the same as those that had been addressed by the military, but now in different contexts. Thus, although the military OR has not stopped developing, there has been a rapid growth in the post-war period of civilian OR, in industry, services and in the State, with the aim of establishing more rational management methods, both in public and private sectors.

At least two factors can be identified that played an essential role in the rapid growth of OR during this period:

- Substantial progress in mathematical techniques available at OR

  After the war, scientists were motivated to further investigate this new discipline, resulting in very important advances such as the Simplex Method to solve linear programming problems, developed by George Dantzig in 1947.

- Computer evolution

  Usually, a large number of calculations are required to treat, more efficiently, the typical problems that characterize OR. However, the development of information technology, materialized in computers, with the capacity to perform arithmetic calculations a thousand times, or even millions of times, faster than man, as well as to process huge volumes of data on the activities of companies, created conditions for these extremely complex problems could be effectively and efficiently solved, thus showing the benefits of using OR.

The methodology of Operational Research

The IO approach applied to mathematical models is specific to the scientific method, which is composed of the following phases:

- Define the problem of interest and gather relevant data
- Formulate a mathematical model to represent the problem
- Develop a computer-based procedure for deriving solutions to the problem from the model;
- Test the model and refine it as needed;
- Prepare for the ongoing application of the model;
- Implement the model.

However, in practice the different phases of the scientific method rarely succeed in the order indicated. Many can be simultaneous and, in several studies, for example, the phase of formulating the problem is only complete when the investigation is virtually finished. The investigation process is usually cyclical. For example, if the model is found to be defective when testing, the problem formulation and model construction can be reviewed and modified. That is, the different phases influence each other during the research work.

Applications of Operational Research

As mentioned above, the fields of application of Operational Research are vast, with the following being the main ones:

- Economy and especially Business Economy, where the most rewarding and inspiring applications and the strongest stimuli for theoretical developments in Linear Programming are located;
- Mathematics, where Linear Programming has driven the achievement of important theoretical results and the improvement of numerical analysis techniques;
- Military, where applications are numerous but usually under-publicized for security reasons.

As examples of these application areas we can refer more explicitly:

- Management of companies (determination of the quantities to be produced of the company's different products according to available resources, existing technological conditions and the market situation.);
- Transportation problems (the cost of transporting a unit of product from each origin to each destination is known, the distribution plan is determined, which minimizes the total transport cost.);
- «Trim-Loss» (determination of the number of units to be cut with certain dimensions in order to minimize the waste involved in relation to the dimensions of production. Examples: paper and cardboard industry, steel, textile, clothing, glass, ...);
- Banks' financial structure (the bank intends to establish the asset structure that maximizes its overall profit, knowing that the legal and management constraints that ensure financial balance must be respected);
- Mixing problems (it is intended to obtain, with minimum cost or maximum profit, one or more products, to satisfy certain technical requirements, through various ingredients possessing a different degree of these technical characteristics. Example: animal feed, fertilizers, food and pharmaceutical products, metal alloys, paints, gasoline.);
- Agricultural Planning (the problem is to allocate scarce resources, such as arable land, labor, water, etc, to the production of various goods in order to maximize the exploitation result.).