

CONSIDERATIONS REGARDING THE VALENCE AND DIVERSITY OF OPERATIONS RESEARCH MODELS

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Abstract: *Operations research(OR), also called decision optimization science, is the one that provides mathematical models meant to lead to finding the optimal variant in an economic, military, social, political, etc. type of activity. These are methods with a major potential, highlighted since the emergence of the models used in World War II actions and later in various other fields, especially in western countries. This paper aims to highlight the benefits of using OR techniques over time and especially to highlight its applicability. In this paper we summarize the presentation of the evolution and contributions of Operational Research in various fields until the '60s, a future paper will deal with the time frame 1960-2020.*

Keywords: Operations research

1. The emergence and evolution of OR until the middle of the twentieth century

Operations research (OR), is a discipline that is part of Applied Mathematics and deals with the creation of mathematical models of decision optimization, which is also called the *science of decision optimization*. The traditional term *Operational research* is used in the UK specialty literature.

In this paper we will refer to the emergence and evolution OR until the '60s because the modern stage of this subject will be addressed in a future paper, being a relatively vast material.

When and how did this study discipline come about and why is it important for the military field?

To answer this question we must first note that OR consists of several disciplines including: mathematical programming, game theory, graph theory, inventory, expectation theory, equipment theory,

production operational programming and others [3]. These disciplines were considered basic when we talk about OR in the '60s and '70s. Later, new disciplines emerged that completed the configuration of what we call today OR. A particular aspect of the emergence and evolution of this new science must be taken into account. We mention once again that the OR is composed of different disciplines that appeared at various historical moments, some of which have their origins even two or three centuries before; in the literature dedicated to this fact, it is considered as the moment of the appearance of the OR that of the appearance of its name and the relatively fast creation of the first structures related to the study and application of specific methods. We will continue to address this issue.

The origins of OR as a name and then as a science are in the UK, in the middle of the twentieth century, more precisely in 1937.

We make a brief reminder of the conditions that favored the emergence of this new science. It should be noted that the nineteenth century brought through a number of scientists new interpretations and visions related to the management of enterprises or financial-economic entities, the use of statistical, mathematical approaches, generally quantitative methods for the analysis of industrial and economic performance. Following the first industrial revolution in Britain and developed countries in Europe and the United States, which ended in the late nineteenth century, there were some major changes in social life, in the economic and financial structure of those countries: increased industrial production due to the use of machines and new technologies, the emergence of new industries and strong industrial centers based on capitalist relations, the emergence of inventions that led to the decline of manual labor replaced by machines and then implicitly changed the organizational structures of companies.

These major changes in the evolution of capitalist society continued during the late nineteenth and early twentieth centuries when human society in general gained impulse through major discoveries in electricity, automotive, aviation, industrial and agricultural production, shipping. From this moment, another approach appeared necessary for the study of the different decision-making processes of technical, economic, military nature, which would offer a safer and more efficient fulfillment of a certain pursued goal.

One of the promoters of this mode of analysis was Frederick.W. Lanchester (1868-1946) who had contributions in the automotive and aeronautical industries in the early twentieth century. He has published a number of articles in the journal *Engineering*, founded since 1865, among the important results being what are called *Lanchester's laws*, which are differential equations used to calculate strengths in a technical system, but also in the military.

The computational techniques used by Lanchester were later incorporated into the methods of OR, hence the recognition of this author as a pioneer of this discipline by establishing the Lanchester Prize in the USA since 1955 for achievements in the field of Operations Research.

The years following the First World War were marked by a series of scientific accumulations on the organization and mode of action, the functioning at the decision-making level of some organizations and we refer especially to those in the military field. An extremely dynamic sector in UK, developed especially after 1930 when Nazi Germany by the ascension of Hitler, but also Japan by the invasion of Manchuria in 1931 began to endanger other world powers, was the aviation of the UK and of the royal navy who increased their numbers and fighting technique. In this context, new management methods were needed, especially to increase the efficiency of the means used.

One of the famous cases known for using the term Operations Research for the first time is related to the Royal Air Force (RAF) which created the world's first chain of radar stations, Chain Home in Bawdsey, Suffolk on the east coast of Great Britain in 1936. The experimental radar station had Robert Watson-Watt, the inventor of the radar, as superintendent; this together with A.P. Rowe, another specialist, helped establish the term Operational Research in 1938, which was assigned to a group of specialists *Operational Research Section* (ORS) to find how radars could be better used to identify and destroy enemy aviation, creating a kind of "total system" of interception and destruction of enemy aviation [4].

The ORS continued to operate until the end of the war under the name *ORS Coastal Command* under the leadership of Professor P.M.S. Blackett, as director since 1942, with the purpose of using radars in connection with aviation to neutralize German naval and air attacks. The methods

used by the ORS during the war highlighted the advantages of using operational research methods for the efficient use of aviation and naval resources. In 1943 Blackett presented a paper "A Note on Certain Aspects of Methodology of Operational Research" which highlighted numerous OR techniques developed in the UK through ORS [5]. The success of the use of these methods in the British Armed Forces led to their implementation in the methods of US aviation and naval groups as well as in Canadian aviation since 1942 [4]. The collaboration of the US and British Armed Forces in the field of OR began in 1941 when a group of American specialists were sent to study the OR methods used in the bombing of the RAF [5]. The ORS functioned until the end of the war, diversifying its methods and spheres of activity, with an increased number of specialists for this new field of analysis and decision. At the end of the war the RAF had over 200 officers and 365 scientists employed in the use of OR in military actions.

It should be noted that P.M.S. Blackett received in 1948, the Nobel Prize for his contributions to the field of nuclear physics and cosmic radiation, but also for what he achieved through the new decision-making methods during the war. In 1946 he received the US Medal of Merit for Pioneering Military Operational Research [1].

We presented the evolution of OR in the UK, the birthplace of this new science, until the end of World War II. We will review some aspects of the concerns in this field of scientists from outside the UK.

During the Second World War, American specialists also made an important contribution to the development of the OR. Philip McCord Morse (1903-1985) should be mentioned, he is an American physicist perceived as a parent of OR in the USA due to his contributions in this field. He was the first president of the *Operations Research Society of America* in 1952. During the war

in the ORS he became familiar with the methods of the OR. In 1942 an OR structure was formed in the USA named ASWORG for anti-submarine fight, which in 1944 was called OR Group. Morse together with some specialists, notably G. Kimball, developed a series of models used in naval combat. Also in 1942, the *Mine Warfare Operations Research Group* (MWORG) was created as part of the US Navy structures, considered to be the first OR organization in the US Army. In mid-1942, there were more than 90 scientists working at MWORG who were collaborating with the Blackett-led group in the British Navy. After the Second World War, the OR gradually passed into the non-military field as a valuable tool for application in activities of public interest, a fact actively supported by P.M. Morse. An example is that in 1952 he created at the prestigious Massachusetts Institute of Technology, an OR center run by P.M. Morse until 1969. Referring to other contributions of OR pioneers, we must mention John von Neumann, a famous mathematician of the twentieth century, born in Budapest in 1903 and then naturalized in the USA where from 1930 until the end of his life in 1957, he worked at Princeton University. From 1933 he was at the Princeton Institute for Advanced Study where he worked with Albert Einstein. Neumann has made major contributions in many areas of mathematics, physics, economics, and computing, which should be widely presented. In terms of OR, it is worth mentioning his contribution to the field of game theory through the minimax theorem of 1928 which is considered to have laid the foundations of this new discipline and then through a famous work published with Oskar Morgenstern in 1944, *Theory of Games and Economic Behavior*. His studies in the field of Game Theory were preceded by some important results, some starting from the 18th century, but the most notable were at the beginning of the 20th century, among which we list:

- the German mathematician E.F.F. Zermelo in 1913 through the work *Über eine Anwendung der Mengenlehre auf die Theorie des Schachspiels* (On an Application of Set Theory to the Theory of the Game of Chess)

- Émile Borel, a French mathematician with interests in various fields of mathematics, had contributions in the study and foundation of game theory, being the first to introduce strategic games, an important work appearing in 1921.

Game theory developed almost simultaneously with another discipline, namely Linear Programming, especially in the post-1940s.

One of the most representative mathematicians for the field of Linear Programming is George Dantzig (1914-2005). He is the one who in 1947 formulated the model of the linear programming problem and found a famous algorithm called *simplex*, for solving these problems. Another important contribution of this mathematician in the field of OR is the one related to the stochastic programming that he was preoccupied with after this period.

Another author who contributed to the development of Operational Research is L.V. Kantorovich (1912-1986), a Russian mathematician (later in the Soviet state) made a major contribution to the development of linear programming and its use in the allocation of resources. In recognition of his contribution in this domain was the award of the Nobel Prize in 1975. An important work by this author appeared in 1939, *Mathematical Methods in the Organization and Planning of Production*. There are many moments and personalities that should be remembered for this early period of the OR, but we will move on to another stage, that of the post-war years. Naturally, we were saying that the OR methods used in the war were transferred to the civilian field. British and American industry have adopted OR since the 1950s, faster in the UK, but relatively

quickly in the US, too. The introduction of OR in universities hastened the expansion of this discipline. The Johns Hopkins University and the Massachusetts Institute of Technology were the first to introduce OR courses in 1948. Case Institute of Technology in Cleveland was the first university to organize a master's degree in OR in 1952. The first doctorates in OR were awarded by Johns Hopkins University and the Massachusetts Institute of Technology in 1955. All major US universities introduced OR discipline into the academic curriculum in the early 1950s. The development of electronic computers, especially in the United States after the war, was an excellent and necessary tool for working with OR methods. Among the first important results were those of Dantzig who, together with W. Orchard-Hays, developed in 1952 a code based on punch-cards. In the following years, especially after 1960, by improving the transistors that revolutionized computers, the possibilities of using computers in the field of OR increased.

The development of informatics has made a major contribution to the use of operational research methods in various fields.

In the post-war period, other subdisciplines of OR developed, even if their roots are far back in time, the main reason being that imposed by practical needs. For example, a well-known and easy model is called Graph Theory, which operates with the notion of graph that can express either a road transport network, rail, but also other activities of the most diverse, from a company to the most complex systems. Euler is considered the founder of this discipline through a study published in 1736 known in the history of mathematics as the *Seven Bridges of Königsberg* by which he solved a practical problem of the city. From him a lot of authors have been concerned with this field. However, the one who is considered the founder of this field is Dénes König (1884-1944) Hungarian mathematician who wrote the first book of

graph theory *Theorie der endlichen und unendlichen Graphen* in 1936 and which marked a turning point in the evolution of this discipline. Later, a French mathematician Claude Berge (1926-2002) had a major contribution to the development of Graph Theory since 1958 when *Théorie des Graphes et ses applications* appeared.

We referred only to some of the disciplines which compose OR. We mentioned earlier that there are other disciplines that are part of the OR, the complexity and diversity of the field being vast. With wide applicability in almost all fields, this science with clear origins in the military field has proven its usefulness by imposing itself as an essential element in what is called decision-making, efficiency in the use of resources of any kind. Western states have understood the advantages of using this science and have implemented it in various fields by creating structures at the level, structures, organizations and companies specializing in the use of OR methods. Next we will review some of the concrete applications of OR from the beginning to the 60's.

2. Applications of OR in various fields

We will present some of the uses of OR in the early periods of this science and until the 60s, after this period the evolution of this science being the subject of another work by the author.

Since the 19th century and even before, methods of OR have been used to solve problems in everyday life or in various scientific fields. An example of this is the use of elements of game theory by A.A. Cournot (1801-1877) in the economic field and not only. This French mathematician is considered one of the founders of this discipline because in 1838 he wrote the work *Recherches sur les Principes Mathématiques from Theorie des Richesses*, in which he used elements of game theory to describe the economic competition between suppliers. Game theory has been used in many ways since its inception; that

of biology used these methods since C. Darwin and later in 1930 by R. Fisher, the famous statistician in the field of genetics and natural selection.

Another field of use of OR was the naval one for the optimization of transport. For example, at the end of 1916 studies on the naval transport of the British navy by these methods led to the establishment of the convoy method as the optimal strategy of commercial transport (iron ore from Sweden transported through the Norwegian port of Narvik) to eliminate losses by sinking ships by enemies. during the war, given the more than 5,000 departures/arrivals of ships weekly from British ports.

In the technical and industrial field there were numerous uses of OR. I mentioned in the first paragraph the achievements of Frederick.W. Lanchester in the early twentieth century in the technical field using methods of OR.

Inventory optimization as a basic discipline of OR has been in the attention of many theorists and practitioners. An important step in this area was in 1913 through a work by Ford W. Harris who created a model that became a classic in Inventory optimization called *economic order quantity* which marked practically an important landmark in the evolution of OR.

In the military field, the optimization of radar action on the east coast of the UK since 1937 through new methods was practically the beginning of the creation of this new science and as we presented earlier during the war was structured in what it is today.

The importance of OR is highlighted by the fact that it became an academic discipline after 1950. Strong societies of OR are created in almost all developed countries with various publications in this field. In 1952 the Operations Research Society of America was established.

Operational Research Society was founded in the UK; initially the OR Club was created in 1948 consisting of five leading

personalities who led the work of the ORS in World War II: Sir Charles Goodeve, Lord P. Blacket, Dr. C. Gordon, Sir. Charles Tizard. In 1951 it was transformed into the Operational Research Society which in 1964 had reached 1250 members and now 3500. The first issue of the Operational Research Quarterly appeared in 1950. The International Federation of Operational Research Societies was established in 1955.

Speaking of what OR is, a definition that expresses its valences appeared in 1962 in the Operational Research Society: "Operational Research is the attack of modern science on complex problems arising in the direction and management of large systems of men, machines, material and money. in industry, business, government and defense".

Immediately after the war, OR methods are applied in the economy, industry, agriculture, transport, the social field, in almost all aspects of society where decisions are made. The financial advantages of using OR in an activity are obvious by choosing the optimal course of action.

In the USA, in 1953, 75% of industrial development research expenditures were for the implementation of OR in the force fields of industry: aviation, electrical, chemical machinery, engineering, oil industry.

The military has kept the preoccupation with the use of OR methods. For example, in the main structure of the US Army there is The Operations Research Office which has implemented since the '50s models of this discipline for strategic issues, combat, logistics, human resources, etc.

3. Conclusions

Taking into consideration the above presented we can conclude that OR is an extremely useful and powerful tool in the decision-making process, a science that provides models that allow a scientific approach, based on efficiency and optimization of any leadership act. It is up to the organizational structures to determine to what extent they will use such methods, but it is certain that if a scientific act of leadership is desired, OR methods are a useful and relatively easy solution.

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