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Operational Research

1.1. A history

Like logistics, operational research (OR) emerged in a military context. The term can be attributed to Watson-Watt[1] around 1940, becoming more widely known because of Patrick Blackett[2] who, during the Second World War, put together the first OR team to resolve air defense problems and then problems surrounding supplying troops.

Although not yet bearing the name, OR developed out of mathematics and problems relating to mathematical expectation or combinatorial analysis between the 17th and 19th Centuries. Blaise Pascal[3] worked on the problems of decision making in uncertainty and Gaspard Monge[4], considered the father of optimization, studied the problems of cuts, fills and defilades. In the early 20th Century, stock management, with the famous Wilson formula[5], brought OR into the modern world.

After the Second World War, many large businesses started using OR, a phenomenon that was making sweeping progress. It would be taught at Massachusetts Institute of Technology from 1948 before spreading into countless

1 Sir Robert Alexander Watson-Watt (1892–1973), a Scottish engineer specializing in radar.
2 Patrick Maynard Stuart Blackett (1897–1974), physicist specializing in, among other subjects, nuclear physics. Inventor of the “Wilson cloud chamber”.
3 Blaise Pascal (1623–1662), a French mathematician, physicist, philosopher and theologian. In 1641, he invented the first calculator (the “Pascaline”).
4 Gaspard Monge (1746–1818), count of Péluse, French mathematician specializing in descriptive geometry, analytical geometry and infinitesimal analysis.
5 Also known as Economic Order Quantity; it calculates the optimal supply period of a production system. It was formulated by Harris in 1913 and realized by Wilson in 1934.

other universities and higher education institutions throughout the world. Nowadays, OR is known as a *decision support* tool.

1.2. Fields of application, principles and concepts

OR can be found within countless services in a business. It is often invisible, like logistics, and the two work in close collaboration.

Its presence is, however, more regularly found in vertical applications such as scheduling and planning, production management, quality, purchase and supply, stock and storing management, conveyance, expedition and transport, commercial action, management control and human resource management.

Methodologically, the use of OR is supported by well-defined principles resulting in the conceptualization of an often transversal approach through the chain system of the business.

The approach can be divided into a number of phases:

– identifying the problem;

– modeling the problem;

– solving the problem;

– validating the solution;

– implementing the solution;

– improving the solution.

COMMENT. – *Section 1.2.1 aims to clarify the general methodology to be implemented so as to formalize an OR problem as well as to define the specific vocabulary used by logisticians*.

1.2.1. *Identification*

Identification is by far one of the most difficult phases. At this stage, one or more *objectives* and a set of *constraints* need to be defined.

While at first glance this may seem simple, on closer examination it quickly takes on a complexity that often lies beneath the surface. For instance, in the case of the transportation of a load from one place to another, it could be said that the aim is to reach the destination by spending the least amount possible on the delivery of goods. The constraints are the potential routes and their respective mileage, the choice of one or more suitable vehicles depending on the mass being transported, the consumption of these vehicles, the cost amortization per kilometer, etc. The delivery point at the destination, however, may have specific opening hours, its storage capacity may be limited, etc.

It is clear to see how the objective itself becomes a source of constraints. It may perhaps need to be redefined, with some of the previous constraints transforming into a new objective in reality, such as for instance, optimal transportation and delivery time.

Constraints are generally equalities or inequalities that constitute equation systems that are difficult to handle and solve. The objective is, in many cases, attached to a function whose *maximization* or *minimization* is required. This may also be the establishment and the verification of a relation. There are often numerous criteria that are poorly defined. The success of this initial phase – the identification of the problem – is crucial as it is where the future problem of the OR is formulated.

Since businesses have been implementing quality management by modeling each of their key actions on one or a number of processes, logisticians have been able to draw on these resources. Nevertheless, it is rare for everything to be formalized enough so that objectives and constraints can be correctly defined. Only an accurate and detailed analysis, as well as collaboration with those on the ground, will provide the elements required for the problem in question to be correctly modeled.

1.2.2. *Modeling*

At this stage, the logistician will formulate an elementary description of the project by defining a set of variable integrated into equations, inequalities, systems, functions or relations. The nature of these variables can be quantitative or qualitative.

All units (kg, L, g, m/s, h, square meter, square kilometer, cubed meter, °C, °F, W, Kwh, etc.) are possible and in a diverse range of formats: integer, decimal, real, rational, monetary, hourly, logical, binary, personalized, etc. They may be input, output or control variables. Constant and random values may intervene. A model is *deterministic* when the set of its parameters is known with certainty or *stochastic* when its parameters are uncertain.

Variables can represent the known or unknown values of a problem: they are often called *alternative*. They face *restrictions* that are developed and contained within constraints with a view to obtain a definite result or solution in the form of an *objective function* to be optimized.

A model is built based on a set of properties:

– *real properties* that belong to reality;

– *formal properties* that only belong to the model;

– *compatible properties* that adapt the model so that it fits with reality.

Depending on the chosen or imposed properties, logisticians are able to generate a *perfect model* when their model only contains the properties existing in the limited perimeter of the problem or a *complete model* when all the existing properties are taken into account.

The model can consist of functions that meet a number or prerogatives:

– explain the situation, present the causes and effects inherent to the problem;

– provide a solution enabling the variables and constraints of the problem to be acted upon so as to obtain a solution that is close to the optimum;

– integrate projected data to improve the solution.

To conclude this section about modeling, it can be said that building a model is based on hypotheses and a choice of mathematical tools.

Hypotheses are built by combining different principles:

– *Linearity* that enables the elaboration of sums with constants, variables and constants multiplied by variables or even multiplying or dividing constants between themselves. In contrast, it prohibits the product or the quotient of two variables. Mathematically, linearity determines whether a system has a response close to a straight line.

– *Divisibility* used to find quotients between variables or variables and constants.

– *Convexity* implies that constraints are linear expressions.

– *Statistical independence* that gives perfect autonomy to a sequence of events (this is rarely the case in reality as causalities are often found between a number of events).

– *Stable condition* that presupposes no change during a defined time period.

– *Absence of memory* that consists of saying that a state obtained at the present moment is sufficient for determining a forecast independent from the past or future.

The mathematical tools that can be used to solve the problem are numerous and are borrowed from algebra, geometry and statistics. To name a few:

– functions;

– integral calculation;

– linear equation systems;

– series;

– numeric sequence;

– matrices;

– graphs;

– Markov chains;

– and so on.

1.2.3. *Solution*

Solution methods are generally iterative, linking solution to solution until the optimum is reached. However, the latter is not always reached and in this event a satisfactory solution is deemed sufficient. In the first case, we talk of *exact solution methods* and in the second of *heuristic* solution methods. Widely used methods employ the processes of *analytical solution*, *deterministic algorithms* or *simulation procedures*.

Graphs or algebraic methods may also be used depending on the number of variables and constraints that need to be processed. Graphs are often restrictive as they can only work within the plane or space and thereby limit the number of variables that can be processed. Many algebraic methods arrive at the same solution.

Computer tools available nowadays can process complex calculations in a very short space of time and approaches using successive approximations are possible. Computer tools are also of great importance when a simulation is required.

1.2.4. *Validation*

In this phase, the obtained solution is studied with regard to the constraints and objective to be reached. Two cases that may be validated can be defined in the following manner:

– an *optimal solution*, which optimizes the objective function;

– an *acceptable solution* where a set of values obtained will meet all of the constraints.

A logisticians' job is not done merely when a solution has been found; the solution must be checked to ensure that it corresponds to the true reality of the situation for which the model was defined.

If the result is not satisfactory, a sampling error may have occurred in the variables used. The chosen relations, equations or statistical laws may not be adequate and so a detailed check takes place and the model must be looked at again for corrections.

1.2.5. *Implementation*

Once the solution has been validated, the method developed can be formalized and applied to other scenarios using similar constraints and the same objective. The use of computer tools offers greater flexibility and almost limitless calculation power in terms of the implementation of different models. To deal with these, logisticians can turn to *spreadsheets* (Microsoft Excel or others) or more specific software such as *project managers* (Microsoft Project, Sciforma, Microplanner, etc.) and *flow simulators* (ExtendSim, Flexsim, Arena, Witness, etc.).

These tools have several irrevocable features:

– the option to work collaboratively;

– the option to work with a network;

– the option to exchange and publish online.

1.2.6. *Improvement*

When a method produces a solution to a given problem, it is not clear whether the solution could be improved on a technical level (or a mathematical level in our case) or through the detail obtained in the results.

It can be interesting to analyze the decisions made by applying the results in real life. What is their impact in conceptual or organizational terms? Could they be improved? Should other factors be taken into consideration? Is the optimum obtained unalterable? Have all contextual elements been included? Can we rationalize a number of processes for which the operational model has been designed?

To conclude, like a doctor dealing with a patient, a diagnosis must be made so as to predict a justified and justifiable improvement of the model.

1.3. Basic models

Over the years research in OR has created countless algorithms and diverse and varied methods adapted to precise fields of application encountered within all logistics systems.

In this book, I have tried to bring together the main categories of problems encountered by adapted OR tools and their often very specific models:

– linear programming;

– dynamic programming;

– optimal paths;

– scheduling;

– trees, rounds and transport;

– maximal flows and networks.

I certainly have not considered everything; there are undoubtedly other subjects that are not discussed. However, in my opinion, this book deals with the most fundamental and current topics.

1.4. The future of OR

In increasingly complex environments, operational research and decision support (ORDS) is becoming increasingly commonplace. It supports managers when making strategic choices that boost the competitiveness of a business.

Although it remains the prerogative of specialists such as logisticians, engineers and financial experts, gradually, since the 1990s, OR has been entering commercial companies and industrial manufacturing after a long period remaining in the academic sphere. Countless tools and applications have emerged bringing OR to non-specialists.

In a context where globalization has become monumental, where competition is fierce, where stocks are expensive, where management decisions have become complex and where just-in-time manufacturing tends to be dominant, OR is often essential and seems to have a bright future ahead.

Although in France we remain behind our European neighbors as well as the United States, there has been a real breakthrough of ORDS in this second decade of the millennium.