Operations Research in Engineering Management

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Abstract

Operations Research has had undertakings as early as the third century when Hieron, King of Syracuse, asked Archimedes to devise means for breaking the Roman naval siege of his city but more clear examples of OR were evident during WWI when political figures made attempts to analyze military operations mathematically. World War II marked the beginning of Operations Research as an organized research. Britain was the first to utilize OR because they already had an OR organization in existence. OR finally crossed the Atlantic to the America's a few months later as both the Army Air Forces and the Navy began work to analyze different war time situations. After the war, OR proved to be very successful that many military operations were faced with considerations on how to continue their field of study and groups were formed within the military structure to continue research. The economic situation that the war had caused began conversion of industries from wartime production to production of goods for the private consumer. The transition from war to peace created a highly competitive economy. Businesses needed to be efficient and profitable. This caused business to analyze their business operations and thus OR found another home.

As discussed above, OR began in the military and then emerged in all aspects of government. It then spread to the banking and financial districts, airlines, and car manufactures. Now it is present in every industry. Operations Research involves many facets of discipline and tends to consider new courses of action to take that make changes to an organization over long periods of time. As one knows, change doesn't happen over-night.

What is Operations Research?

Since the operating systems studied by OR specialists arose in a wide variety of industries and government environments. It follows that the results of their research frequently make important contributions to the solution of problems of choice, policy, and planning. It can be determined that OR is a flexible and powerful tool to management in improving their operations. The methods of Operations Research were rooted in the basics of science. . An OR team (in some companies this may be a single individual) consists of trained researchers that incorporate their own techniques and methods from their fields to the basics of science. The first step is to formulate the problem, after which a mathematical model is generally constructed to represent the system being studied. Mathematical models, or conceptual models, are usually equations or formulae developed to relate important factors of the operations studied. The factors can then be tested, and operated on mathematically to determine the effects of changing the values of the variables. Basically, OR can be characterized with the following statements:

- Research on the operations of the whole organization to determine the problem and then optimize the operations to improve the organization.
- Application of the newest methods and techniques.
- Application of the methods and techniques of the older management sciences.
- Development and use of analytical models in accordance to the basic sciences.
- Design and use experimental operations that give an insight into behavior of actual operations.
- Use of integrated and creative multi-disciplinary team research to solve complex operational problems.

<u>A simple definition: Operations Research is concerned with making the whole system work with maximum and effectiveness and least cost.</u>

Steps of Operations Research

OR utilizes modeling as a way to recognize the problem and then ultimately solve the problem. From recognition to the decision; the OR process is made up of eight distinct phases:

1. **Recognition of a Need:** This phase is defined as the perceptions of needing some sort of resolution or need for improvement.
2. **Problem Formulation:** This phase takes the problem, defines it, and assigns inputs to be used in the next phase. These inputs are variables, parameters and constraints.
3. **Model Construction:** This phase takes the variables, parameters and constraints and constructs a mathematical representation of the problem defined in phase 2. The purpose of this phase is to create the best model so that the variables can be changed and observed.
4. **Data Collection:** This phase utilizes the model and the different inputs to the model, which reflect actual problem conditions. Data that is hard to collect include: preferences, opinions, and quality. These items are known as soft data.
5. **Model Solution:** This phase actually utilizes the input data and mathematical algorithms to produce results.
6. **Model Validation and Analysis:** This phase is a self-checking phase. It makes sure that the first four phases are free of errors and that the model accurately represents the problem hand. If there are errors in any of the processes, phase 2 to phase 5 must be redone.
7. **Interpretation of Results:** This phase is concerned with examining the results and makes sure that the solution is the optimum or best solution. Tradeoffs can occur and this is known as sub-optimization.
8. **Decision Making and Implementation:** Once a project reaches this phase, the OR is done and a decision must be made. The outcome of the decision may not directly be related to the results. Other existing external factors play a part in the decision process. These factors can be personal, ethical or political.

Whatever the reason, the OR process has been accomplished and this gives management another tool for making a decision on the problem.

Tools of Operations Research and Model Application

Now that the steps of OR have been identified, the tools to solve the problem must be described. These models or algorithms are utilized in phase 3-5 to produce results and data collection. Models can be broken into two categories. They are the deterministic and stochastic. Each model is created to specify a certain problem or application needed to be solved. Deterministic models are the simplest types. There are no uncertain or probabilistic variables and no optimization. They are straightforward and utilize formulas and graphs to represent the data. Within the deterministic category are:

- **Linear Programming:** Problems involving the allocation of scarce resources such as materials, manpower, machine time or space. Extensively used in problems of blending ingredients, scheduling, manpower planning and economic planning.
- **Transportation:** This is a special case of Linear Programming. This involves problems where one resource is stored or made in several locations and needed in several other locations, e.g. warehousing and distribution.
- **Assignment:** This is a special case of Linear Programming. This involves problems such as assigning n drivers to n cars in order to minimize cost or n operators to n tasks to minimize time.
- **Integer Programming: :** This is a special case of Linear Programming. This involves problems of resource allocation with the restriction that certain resources are only available in fixed-size units, which can't be split up. Also used in problems of route selection and other problems involving 0-1 variables.
- **Goal Programming:** Problems of resource allocation.

Stochastic models incorporate uncontrolled variation in some way. The widest use of these models is to the use of statistical forecasting. Within the stochastic category are:

- **Statistical Forecasting Methods:** Making short to medium forecasts of future values of a time series of data. Typically used for predicting sales, spare parts demands, etc.
- **Simulation:** Problems that involve uncertainty in the system – e.g. in production lines, shops, transport services, manpower modeling. This model is to mimic real life systems and used to evaluate the real system.
- **Game and Hypergame Theory:** Competitive problems where there is some kind of opponent. This tends to be more theoretical than practical.
- **Decision Analysis**: Problems involving a decision or a series with a small number of options and a small number of outcomes. Examples include decisions on whether or not to test market new products, bidding strategies for contracts and diagnosis of medical condition.
- **Replacement Theory**: Problems involving the failure of components and/or machines.
- **Search Theory**: Problems involving something with the use of limited resources.
- **Queuing Theory**: Problems where customers are queuing for service of some sort. Examples include shops, banks, telephone exchange, repair of machines, and job-shop scheduling.

  The following methods can be either used in deterministic or stochastic models:

- **Dynamic Programming:** Problems involving a series of similar linked decisions, differing only in time or space, such as the choice of the shortest route between two points or decisions involving monthly production or storage.
- **Project Network Analysis:** Problems involving sequencing and scheduling a collection of identifiably separate jobs subject to various logical constraints. Used almost everywhere in construction industry.

- **Stock Control:** Problems involving the holding of stocks, raw materials, spare parts, finished goods or stationary.