

The Nature of Operations Research (OR)

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IT262
Operations Research

Lecture 1



Course content

1. **The nature of operations research Linear programming: Formulations and graphical solution.**
2. Algebraic solution: the simplex methods and dual-simplex method.
3. Sensitivity analysis.
4. Transportation and assignment problems.
5. integer programming: cutting-plane algorithms,
6. branch, and bound method.
7. Dynamic programming: examples of the dynamic programming.
8. Models and computations,
9. solution of linear programs by dynamic programs.

Operations Research (OR)

- Operations Research (OR) is a discipline that applies advanced analytical methods to help make better decisions. OR involves the use of mathematical models, statistics, and algorithms to solve complex problems in various industries such as business, engineering, and public services.

Origins of OR:

- Began during World War II (early 1940s) to solve complex military resource allocation problems.
- **Technological advancements** such as:
 - **Simplex method** (George Dantzig, 1947) revolutionized solving linear programming problems.
 - The rise of **computers** accelerated OR's development, making complex problem-solving feasible.

The Nature of Operations Research

- Research on how to conduct and coordinate an organizations activates.
- OR
 - Is also call management science
 - Utilize the scientific method

The Nature of Operations Research

- Process
 - Carefully observe and formulate the problem
 - Gather data
 - Construct a mathematical model
 - Test whether the model represents the actual situation
 - Modify the model as appropriate and validate again

The Nature of Operations Research

Broad viewpoint

- Considers what is best for organization as a whole
- Attempts to identify best possible course of action

Team approach

- Consists of individuals with diverse backgrounds and skills
- Necessary for considering ramifications of problem throughout organization

The Rise of Analytics Together with Operations Research

- Analytics (business analytics)
 - Introduced in 2006 by Thomas H. Davenport
 - Similar in concept to operations research
 - Transforms data into insight to make better decisions
- Big data
 - Refers to the massive amounts of data available today



The Rise of Analytics Together with Operations Research

- Categories of analytics applications
 - Descriptive analytics
 - Identify interesting patterns to describe what is currently happening
 - Predictive analytics
 - Using data to predict what will happen in the future
 - Prescriptive analytics
 - Using data to prescribe what should be done in the future



Major Fields of Application for OR

- Supply Chain Management: Optimizing logistics and inventory.
- Healthcare: Improving patient scheduling and resource utilization.
- Finance: Portfolio optimization, risk management.
- Manufacturing: Production planning and control.

Role of Models in Operations Research

- Models are simplifications of real-world problems.
- They help in understanding the relationship between decision variables and outcomes.

Phases of a Typical OR Study

1. Define the problem and gather data

Identify the problem of interest and collect all relevant data.

2. Formulate a mathematical model

Develop a mathematical model that accurately represents the problem.

3. Develop a computer-based solution

Create a computer-based procedure to derive solutions from the model.

4. Test and refine the model

Test the model and make necessary adjustments to improve its accuracy.

5. Prepare for ongoing application

Ensure the model is ready for continuous use as directed by management.

6. Implementation

Put the model into practice and monitor its performance.



Defining the Problem and Gathering Data

- Elements of problem definition
 - Identify the appropriate objectives
 - Identify constraints
 - Identify interrelationships with other areas of the organization
 - Identify alternative courses of action
 - Define the time constraints

Defining the Problem and Gathering Data

- OR team typically works in an advisory capacity
 - Management makes the final decisions
- Identify the decision maker
 - Probe his/her thinking regarding objectives
- Objectives need to be specific
 - Also aligned with organizational objectives

Defining the Problem and Gathering Data

- Example of an objective in a for-profit organization
 - Maximum profit in the long run
- More typical objective
 - Satisfactory profit combined with other defined objective

Defining the Problem and Gathering Data

- Parties affected by a business firm operating in a single country
 - Stockholders (owners)
 - Employees
 - Customers
 - Suppliers
 - Government (nation)
- International firms obligated to follow socially responsible practices

Defining the Problem and Gathering Data

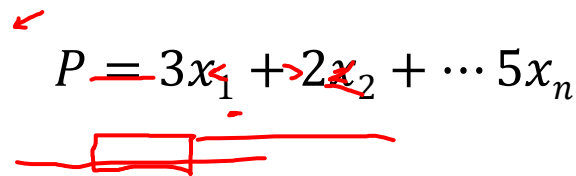
- Gathering relevant data necessary for:
 - Complete problem understanding
 - Input into mathematical models
- Problem: too little data available
 - Solution: build management information system to collect data
- Problem: too much data available
 - Solution: data mining methods

Formulating a Mathematical Model

- Models
 - Idealized representations
 - Examples: model airplanes, portraits, globes
- Mathematical models
 - Expressed in terms of mathematical symbols
 - Example: Newton's Law: $F = ma$
- Mathematical model of a business problem
 - Expressed as system of equations

Formulating a Mathematical Model

- Decision variables
 - Represent the decisions to be made
 - Examples: $x_1, x_2, \dots, x_n$
- Objective function
 - Performance measure expressed as a function of the decision variables
 - Example: profit, P

$$P = 3x_1 + 2x_2 + \dots + 5x_n$$


Formulating a Mathematical Model

- Constraints

- Mathematical expressions for the restrictions
- Often expressed as inequalities
- Example:

$$x_1 + 3x_1x_2 + 2x_2 \leq 10$$

- Constants in the equations called parameters of the model
- Example: the number 10 in the above equation

Formulating a Mathematical Model

- Determining parameter values

- Often difficult
- Done by gathering data

$$2x_2 + 3x_1 \geq 10$$

- Real problems often do not have a single “right” model

Formulating a Mathematical Model

- What are the advantages of a mathematical model over a verbal description of the problem?
 - More concise
 - Reveals important cause and effect relationships
 - Clearly indicates what data is relevant
 - Forms a bridge to use computers for analysis

Formulating a Mathematical Model

- What are the disadvantages of mathematical models?
 - Often must simplify assumptions to make problem solvable
- Judging a model's validity
 - Desire high correlation between model's prediction and real-world outcome
 - Testing (validation phase)
 - Multiple objectives may be combined into an overall measure of performance

Deriving Solutions from the Model

- Sometimes a relatively simple step
- Algorithms applied in a computer using a commercially-available software package
- Search for the optimal solution
 - Common theme in OR problems
 - Recognize that the solution is optimal only with respect to model being used
 - More common goal: seek a satisfactory solution, rather than the optimal

Deriving Solutions from the Model

- Postoptimality analysis
 - Analysis done after finding an optimal solution
 - Very important part of most OR studies
 - Also called “what-if” analysis
 - What would happen if different assumptions were made?
- Sensitivity analysis
 - Determines which variables affect the solution the most

Testing the Model

- Model validation
 - Process of testing model output and improving the model until satisfied with output
- Computer program analogy
 - Find and correct major bugs
 - Determine flaws in the model
- Example of flaws:
 - Factors that were not incorporated
 - Parameters that were estimated incorrectly

Testing the Model

- Process varies with the model
- Check for dimensional consistency of units
 - In all mathematical expressions
- Vary values of parameters and/or decision variables
 - See if output behaves in a plausible way

Testing the Model

- Retrospective test
 - Uses historical data to reconstruct the past
 - Determines how well the model and solution would have performed
- Disadvantages of the retrospective test
 - Uses same data as used to formulate the model
 - The past may not be indicative of the future

Preparing to Apply the Model

- Install a well-documented system for applying the model
 - Includes the model, solution procedure, and implementation procedures
 - Usually computer-based
- Databases and management information systems
 - Provide up-to-date model input

Preparing to Apply the Model

- Decision-support system
 - Interactive, computer-based system
 - Helps managers use data and models to support their decision-making

Implementation

- Benefits of the study are reaped during implementation phase
- Important for OR team to participate in launch
 - To make sure model is correctly translated
- Success of implementation depends on support from:
 - Top management
 - Operations management

Implementation

- Steps in the implementation phase
 - OR gives management explanation of new system
 - How does it relate to operating realities?
 - Develop procedures to put system into operation
 - Responsibility of OR team and management
 - Initiate new course of action
 - OR team evaluates initial experience
 - Gather feedback

Implementation

- Steps in the implementation phase (cont'd.)
 - Document methodology
 - Work should be reproducible
 - Periodically revisit assumptions

Limitations and Challenges in OR

- High dependence on accurate data.
- Complex models may not always be easily understood by decision-makers.
- Not all problems can be quantified or modeled mathematically.

Recap of the Nature of Operations Research

- Operations Research focuses on providing optimal solutions to decision-making problems using analytical methods.
- It is applied across various sectors and industries to solve practical problems.

Conclusions

- Subsequent chapters focus on constructing and solving mathematical models
- Phases described in the chapter are equally important
- There are always exceptions to the “rules”
 - OR requires innovation and ingenuity



Thank You