

Introduction to Operations Research

Introduction to Operations Research (OR)

Key concepts, methodology, and typical applications

1. What Is Operations Research?

Aspect	Description
Definition	A systematic, quantitative approach to decision-making that seeks optimal or near-optimal solutions for complex systems.
Goal	Improve performance, reduce cost, increase efficiency, or achieve a desired objective under given constraints.
Nature	Interdisciplinary – draws from mathematics, statistics, computer science, engineering, economics, and management.
Typical Users	Supply chain managers, transportation planners, finance analysts, health care administrators, military strategists, etc.

2. Core Components of the OR Process

1. Problem Definition

- Identify the decision maker's objective(s).
- List constraints (resources, capacities, policies).
- Clarify the scope (time horizon, level of detail).

2. Model Formulation

- **Decision Variables** – quantities to be determined.
- **Objective Function** – mathematical expression to be maximized or minimized.
- **Constraints** – equations/inequalities representing limits.
- **Assumptions** – simplify reality while preserving essential features.

3. Data Collection & Parameter Estimation

- Gather historical data, forecasts, expert judgments.

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- Use statistical techniques (regression, time-series) to estimate parameters.

4. Solution Methods

- **Exact Algorithms** – Linear Programming (LP), Integer Programming (IP), Network Flow, Dynamic Programming.
- **Heuristics & Meta-heuristics** – Greedy, Local Search, Genetic Algorithms, Simulated Annealing, Tabu Search.
- **Simulation** – Monte-Carlo, Discrete-Event Simulation for stochastic systems.

5. Verification & Validation

- Check model logic (verification).
- Compare model output with real-world performance (validation).

6. Implementation & Monitoring

- Translate solution into actionable policies or schedules.
- Set up KPIs to monitor outcomes and adjust the model as needed.

3. Major Modeling Techniques

Technique	Typical Use Cases	Key Features
Linear Programming (LP)	Production planning, diet problems, transportation	Objective & constraints linear; continuous variables
Integer Programming (IP)	Facility location, crew scheduling, lot-size decisions	Variables restricted to integers (binary or general)
Network Models	Shortest path, max flow, vehicle routing	Graph-based; efficient specialized algorithms
Dynamic Programming (DP)	Multi-stage decision problems, inventory control	Breaks problem into stages; optimal substructure
Queuing Theory	Call centers, hospital ER, manufacturing lines	Models arrival/service processes; performance metrics (wait time, utilization)
Simulation	Complex stochastic systems, risk analysis	Replicates system behavior; no closed-form solution required

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Technique

Typical Use Cases

Key Features

Decision Analysis

Project selection, risk-adjusted investments

Decision trees, utility theory, sensitivity analysis

4. Example: Linear Programming Formulation

Problem: A factory produces two products, A and B.

- Profit per unit: \$40 (A), \$30 (B)
- Labor hours: 2h (A), 1h (B) – total available 100h
- Material: 3kg (A), 2kg (B) – total available 120kg

Model

- Decision variables: