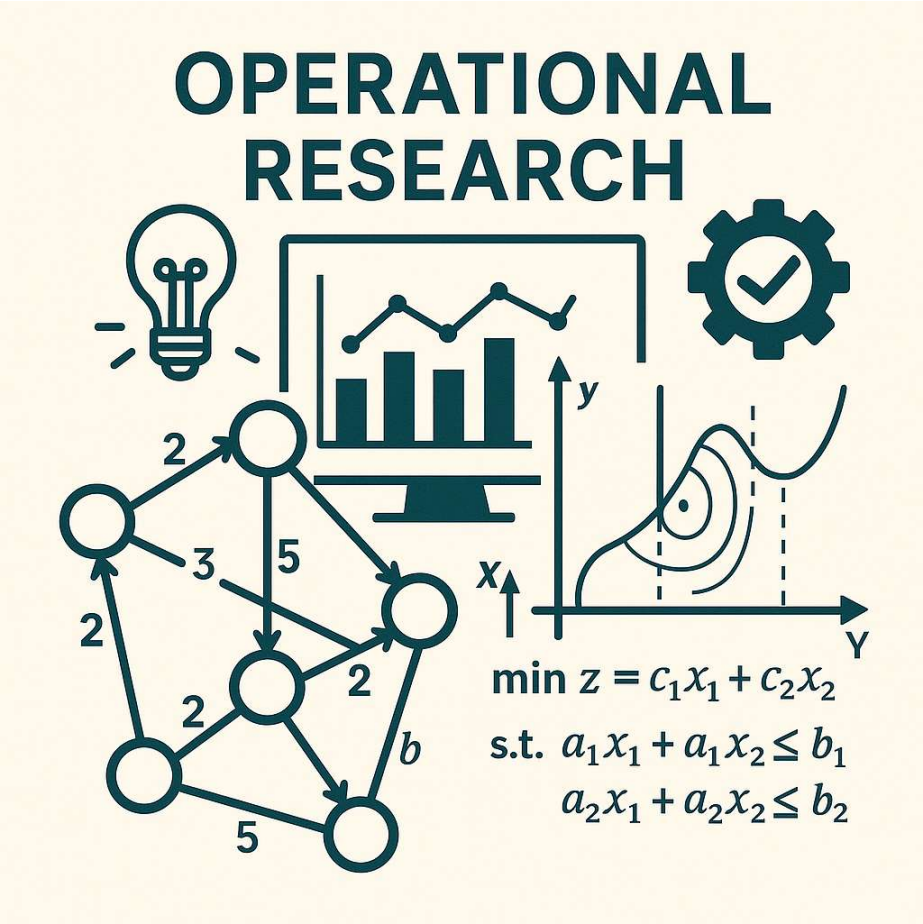
Specialization name : Operational research



Phd program for operations research

Program overview

This doctoral program in **Operational Research (OR)** aims to equip students with the skills needed to conduct advanced research in the field. Doctoral candidates must develop a deep understanding of **theoretical principles** and **practical methods** in operational research. They will become proficient in a wide range of optimization techniques, such as **linear, nonlinear, combinatorial, stochastic, multi-objective, and semidefinite optimization**, among others.

The program provides the tools to **formulate real-world problems** as mathematical and computational models by identifying relevant variables, constraints, and objectives. Its ultimate goal is to enable students to make **original and innovative contributions** to the field of operational research.

Students must be comfortable with **computational tools and programming languages** commonly used in OR, such as **Python, R, Julia, MATLAB, CPLEX, and Gurobi**.

Throughout the program, they will develop skills to **clearly and persuasively present their work**, both in writing (scientific papers) and orally (conferences), while collaborating with other researchers.

Beyond theory, doctoral candidates will explore **practical applications** of operational research in fields like **logistics, supply chain management, production planning, telecommunications, and finance**.

In summary, a PhD in **Operational Research** trains **competent and versatile researchers** capable of solving complex problems using advanced mathematical and computational methods.

Core courses

1. Foundations of Optimization

- Linear Programming (LP)
- Nonlinear Programming (NLP)
- Integer and Combinatorial Optimization
- Convex Optimization
- Duality Theory

2. Stochastic Models & Probability

- Stochastic Processes
- Queueing Theory
- Markov Decision Processes (MDP)
- Simulation Methods (Monte Carlo, Discrete-Event Simulation)
- Reliability Theory

3. Advanced Optimization Techniques

- Dynamic Programming
- Network Optimization
- Multi-Objective Optimization
- Robust and Stochastic Optimization
- Metaheuristics (Genetic Algorithms, Simulated Annealing, etc.)

4. Decision Analysis & Game Theory

- Decision Trees and Risk Analysis

- Bayesian Decision Theory

- Cooperative and Non-Cooperative Game Theory

- Auction Theory

5. Applied OR & Computational Tools

- Large-Scale Optimization (Decomposition Methods)

- Machine Learning for OR

- Supply Chain & Logistics Optimization

- Healthcare OR / Revenue Management

- Software: Python, R, Julia, MATLAB, CPLEX, Gurobi, AMPL

Advanced topics (Additional courses)

1. Advanced Optimization Methods

- Stochastic Optimization : Robust optimization, chance-constrained programming, stochastic dynamic programming.

- Bilevel & Multilevel Optimization : Hierarchical decision-making problems (e.g., Stackelberg games).

- Distributionally Robust Optimization : Handling uncertainty with incomplete probability information.

- Nonconvex & Global Optimization : Branch-and-bound, cutting-plane methods for nonconvex problems.

2. Machine Learning & OR Integration

- Reinforcement Learning for Sequential Decision-Making (e.g., MDPs, POMDPs).

- Optimization in Deep Learning: Neural network training as an optimization problem.

- Data-Driven OR: Prescriptive analytics, stochastic programming with learning.

3. Large-Scale & Distributed Optimization

- Decomposition Methods: Benders, Dantzig-Wolfe, Lagrangian relaxation.

- Parallel & GPU-Accelerated Optimization.

- Federated Optimization: Privacy-preserving distributed decision-making.

4. Network & Combinatorial Optimization

- Quantum Optimization: Quantum annealing for combinatorial problems.
- Approximation Algorithms for NP-hard problems.
- Graph Neural Networks (GNNs) for Network Optimization.

5. Game Theory & Strategic Decision-Making

- Mechanism Design & Auction Theory (e.g., Vickrey-Clarke-Groves auctions).
- Mean-Field Games: Large-population strategic interactions.
- Behavioral OR: Incorporating psychology into decision models.

6. OR in Emerging Domains

- Healthcare OR: Pandemic modeling, personalized treatment optimization.
- Energy & Sustainability: Smart grid optimization, carbon footprint reduction.
- Space & Aerospace Logistics: Satellite scheduling, mission planning.

7. High-Performance OR Computing

- Real-Time Optimization (e.g., for autonomous systems).
- Massively Parallel Stochastic Algorithms.
- OR on Quantum Computers (e.g., QAOA, Grover adaptive search).

8. Uncertainty Quantification & Risk Management

- Worst-Case Optimization (e.g., adversarial robustness).
- Risk-Averse & CVaR (Conditional Value-at-Risk) Optimization.
- Black-Box Optimization (e.g., derivative-free methods).

Complete course table

1. Core Theoretical Courses

Course title	Topics covered
Advanced Deterministic Optimization	Linear/nonlinear programming, duality, KKT conditions, convex analysis

Stochastic Models in OR	Markov chains, queueing theory, Brownian motion, Poisson processes
Integer & Combinatorial Optimization	Branch-and-bound, cutting planes, heuristics, complexity theory
Dynamic Programming & Control	Bellman equation, stochastic control, approximate DP

2. Advanced & Computational Courses

Course title	Topics covered
Robust and Stochastic Optimization	Uncertainty sets, chance constraints, distributionally robust optimization
Large-Scale Optimization Methods	Decomposition (Benders/Dantzig-Wolfe), parallel computing, ADMM
Machine Learning for OR	RL for MDPs, neural networks in optimization, data-driven decision-making
Simulation & Monte Carlo Methods	Discrete-event simulation, variance reduction, metamodeling

3. Specialization Tracks

Track A: Optimization & Algorithms

- Nonconvex and Global Optimization
- Network Flows and Graph Algorithms

Track B: Applied OR in Industry

- Supply Chain & Logistics Optimization
- Healthcare OR & Resource Allocation

4. Tools & Labs

Course Title	Software/Tools
Computational OR Lab (Python/R)	PuLP, CVXPY, SciPy, Gurobi, CPLEX
High-Performance OR Computing	MPI, GPU acceleration, cloud-based optimization

Suggested Textbooks

- *Introduction to Operations Research* (Hillier & Lieberman)
- *Stochastic Optimization* (Shapiro et al.)
- *Convex Optimization* (Boyd & Vandenberghe)