Proposed Syllabus and Scheme of Examination

for

B. Sc. (Honours) Operational Research

under

Choice Based Credit System

DEPARTMENT OF OPERATIONAL RESEARCH
UNIVERSITY OF DELHI
PREAMBLE

Operational Research (OR) is a discipline to aid decision making and improving efficiency of the system by applying advanced analytical methods. As a formal discipline it originated in the efforts of military planners during World War II.

The tools of Operational Research are not from any one discipline; rather Mathematics, Statistics, Information Technology, Economics, Engineering, etc. have contributed to this discipline of knowledge. Today, it has become a professional discipline that deals with the application of scientific methods for decision-making, and especially to the allocation of scarce resources.

The courses in Operational Research offer a unique blend of traditional coursework, practical skills, and real world problem solving experience designed to position students for success in today’s competitive world.
# Proposed Scheme for Choice Based Credit System in B. Sc. Honours (Operational Research)

<table>
<thead>
<tr>
<th>CORE COURSE (14)</th>
<th>Ability Enhancement Compulsory Course (AECC) (2)</th>
<th>Ability Enhancement Elective Course (AEEC) (2) (Skill)</th>
<th>Elective: Discipline Specific DSE (4)</th>
<th>Elective: Generic (GE) (4)</th>
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<tr>
<td>I</td>
<td>Introduction to Operational Research and Linear Programming (Theory + Practical)</td>
<td>Mathematics – I (English/MIL Communication) /Environmental Science</td>
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<td>Statistics – I</td>
<td>Environmental Science/ (English/MIL Communication)</td>
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<td>IV</td>
<td>Production and Inventory Management (Theory + Practical)</td>
<td>Statistics – II</td>
<td>Operational Research Application / Introduction to Information Technology</td>
<td>GE-4</td>
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<td>V</td>
<td>Queueing and Reliability Theory (Theory + Practical)</td>
<td>Optimization – II</td>
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<td>VI</td>
<td>Decision Analysis and Game Theory</td>
<td>Scheduling Techniques (Theory + Practical)</td>
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Appendix-VII 
(Page No. 125-164)
## SEMESTER I

<table>
<thead>
<tr>
<th>Paper Code</th>
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*Project Work/Industrial Training will be offered in the Sixth Semester.*
Core Papers (Credit: 06 each) OR-C-101 to 114

1. Introduction to Operational Research and Linear Programming (Theory+ Practical)
2. Mathematics – I
3. Advanced Linear Programming (Theory+ Practical)
4. Statistics – I
5. Optimization – I (Theory+ Practical)
6. Mathematics – II
7. Object Oriented Programming (Theory+ Practical)
8. Production and Inventory Management (Theory+ Practical)
9. Statistics – II
10. Database Management System
11. Queueing and Reliability Theory (Theory+ Practical)
12. Optimization – II
13. Decision Analysis and Game Theory
14. Scheduling Techniques (Theory+ Practical)

Discipline Specific Elective Papers (Credit: 06 each) (4 papers to be selected)

1. Logistics and Supply Chain Management
2. Quality Management
3. Managerial Economics
4. Project Management
5. Business Data Analysis
6. Time Series and Econometrics
7. Quantitative Marketing and Finance
8. Project Work / Industrial Training (Sixth Semester)

Generic Elective/Interdisciplinary (Four papers to be selected from other Disciplines)

Ability Enhancement Electives (skill based) (Credit: 02 each) (2 papers to be selected)

1. Data Analysis
2. Operation Research Application
3. Introduction to Information Technology
4. Numerical Methods

Generic Elective Papers (GE) (Credit: 06 each) (Any Four papers to be selected by the other Departments /Disciplines)

1. Essentials of Operational Research and Linear Programming
2. Inventory Management
3. Network Models and Scheduling Techniques
4. Integer Programming and Theory of Games
5. Queueing and Reliability Theory
6. Optimization Techniques

Appendix-VII
1. Introduction to Operational Research and Linear Programming

Objective: The objective of the paper is to introduce the basic concepts of Operational Research and linear programming to the students. The paper also emphasizes on the application of Operational research to the real world problems.


Linear Programming: Introduction to Linear algebra. Solution of a system of Linear Equations, Linear independence and dependence of vectors, Concept of Basis, Basic Feasible solution, Convex sets. Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.


References /Suggested Readings:


Practical/Lab to be performed on a computer using OR/Statistical packages

1. To solve Linear Programming Problem using Graphical Method with

   (i) Unbounded solution

   (ii) Infeasible solution

   (iii) Alternative or multiple solutions.

2. Solution of LPP with simplex method.

4. Problem solving using Two Phase method.

5. Illustration of following special cases in LPP using Simplex method
   (i) Unrestricted variables
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution.

6. Problems based on Dual simplex method.
2. Mathematics I

Objective: The objective of the paper is to provide a platform for introduction to linear algebra and calculus for beginning students at the undergraduate level. This course will give the rudimentary idea of Mathematics to be useful in further course of Operational Research.

Matrices & System of Linear Equations: Matrix Algebra, Types of Matrices, Elementary row operations on a Matrix, Echelon form of a Matrix, Rank of a Matrix, Inverse of a matrix, Solution of System of Homogeneous & Non-Homogeneous Equations

Vector Spaces: Definition, Sub-spaces, Linear Combinations, Linear Span, Basis & Dimension, Linear Transformation, Linear transformation on finite dimensional vector spaces, Kernel & Image of a Linear transformation, Matrix of a Linear transformation, Eigen Values, Eigen Vectors, Characteristic Polynomial, Diagonalization, Cayley Hamilton Theorem

Calculus: Functions of one variable: Limit, continuity, Differentiability, Intermediate value theorem, Rolle’s Theorem, Mean value theorem (MVT), Cauchy’s mean value theorem. Taylor series, Maclaurin series, maxima and minima

Reference/Suggested Readings:


3. Advanced Linear Programming

Objective: To enrich the knowledge of students with advanced techniques of linear programming problem along with real life applications.


Suggested Readings


Practical/Lab to be performed on a computer using OR/Statistical packages

LIST OF PRACTICALS

1. Solution of Transportation Problem.
2. Solution of Assignment Problem.
3. Solution of Travelling Salesman Problem.
4. Solution of IPP using Branch and Bound method.
5. Solution of IPP using Gomory’s cutting plane method.
7. Solution of Fixed charge problem.
4. Statistics-I

**Objective:** The objective is to introduce basic Probability theory required for course in Operational Research.

Introduction to the notion of probability, Random experiment, Sample space & Events, Probability defined on events, Algebra of events, Conditional probabilities, Independent events, Bayes’ theorem

Random Variables, cumulative distribution functions, probability mass/density functions, Discrete Random Variables (Binomial, Poisson and Geometric).

Continuous Random Variables (Normal, Exponential, Uniform and Gamma).


Markov inequality, Chebyshev’s inequality, Chernoff’s bound, Central Limit Theorem, Strong Law of Large Numbers.

**Suggestive Reading**


**Online Reading/Supporting Material**

5. Optimization-I

**Objective:** This paper is the sub-field of Optimization that deals with problems that are non linear. The Objective of the paper is to introduce the non linear programming problems and methods to the students.


References / Suggested Readings:


**Practical/Lab to be performed on a computer using OR/Statistical packages**

**LIST OF PRACTICALS:**

2. Solution of Quadratic programming problem by Wolfe’s and Beal’s method.
3. Dynamic programming applications for optimization problems involving:
   i. Additive separable returns for objective with additive constraints.
   ii. Additive separable returns for objective with multiplicative constraints.
   iii. Multiplicative separable returns for objective with additive constraints.
6. Mathematics – II

Objective: This paper is designed to enrich the knowledge of students with understanding of key concepts of advanced calculus and differential equations. This course will enhance students’ ability to explore in the area of Operational Research.

Calculus on $\mathbb{R}^n$: Functions of several variables: Limits and continuity of functions of several variable, partial differentiation.


Laplace Transform, Inverse Transform, Linearity, s-Shifting, Transforms of Derivatives and Integrals, ODEs, Unit Step Function, t-Shifting, Partial Fractions, Convolution, Integral Equations, Differentiation and Integration of Transforms, Systems of ODEs.

Reference/Suggested Readings:

2. S. L. Ross, Differential Equations, John Wiley and Sons, India, 2004
7. Object Oriented Programming

Objective: The objective is to Develop computer programming skills that appropriately utilize key object-oriented concepts


Introduction to C++: Identifier and keywords, Constants, Operators, type Conversion, variable Declaration, Expressions, Statements, Manipulators. Input and Output Statements, Stream I/O. Conditional and Iterative statements.

Function Prototype and definition. Pointers. Classes,, Objects and Members: Class Declaration and Class Definition, Constructors, types of constructors, Destructors, Dynamic memory allocation using new and delete operators.

Inheritance, Single, Multiple, and Multi level. Polymorphism, function overloading and Operator overloading: Overloading unary and binary operators, Files and Streams.

References:


Practical’s based on C++ involving OR problems.

1. Write a program to display Fibonacci numbers upto a specified limit.
2. Solve a quadratic equation for all possibilities using a switch block.
3. Using recursion, find the value of \( n^C_r \).
4. To reverse the digits of a number and find the sum of the digits.
5. To find the roots using Numerical Methods.
6. Write a program to perform basic operations on Matrices
7. Write a menu driven Program for list operations: search, sort, max, and min for string arrays using different functions.
8. Write a program to find the EOQ with and without shortages.
9. Determine performance measures of M/M/1 and M/M/C models.
10. To find the reliability of parallel and series systems.
8. Production and Inventory Management

Objective: The objective of this course is to introduce fundamental issues in production and inventory planning and control and at the same time, developing the students’ modeling and analytical skills.

Introduction to inventory systems, Selective inventory classification and its use in controlling inventory.

Deterministic inventory models: Economic order quantity (EOQ) model, EOQ with finite supply, EOQ with backorders, EOQ with constraints, All-units quantity discounts model.

Single period probabilistic inventory models with discrete and continuous demand, determination of reorder point for deterministic and probabilistic Inventory System.

Introduction to Production Planning and Scheduling, Aggregate production plan, Formulation of lot size production problem: Wagner and Whitin algorithm.

Basic concepts of Just-in-Time (JIT) and Material Requirement Planning (MRP)

Suggested Readings:


Practical/Lab to be performed on a computer using OR/Statistical packages

LIST OF PRACTICALS

1. Problems based on selective inventory classification (ABC and FNS analysis).
2. To find optimal inventory policy for EOQ model.
3. To solve multi-item inventory model with different constraints.
4. To solve All-units quantity discounts model.
5. To find optimal inventory policy for Probabilistic inventory model with discrete demand.
6. To find optimal inventory policy for Probabilistic inventory model with continuous demand.
7. Solution of procurement/production scheduling model.
9. Statistics - II

Objective: The objective is to introduce Statistical thinking required for course in Operational Research.

Sampling distribution: Random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean and variance, standard error, chi-square, t and F-distribution.


Interval estimation: Constructing confidence intervals for population parameters (mean and variance).

Testing Hypothesis: Tests on population parameters, Tests on independent and paired samples, Neyman-Pearson lemma, Uniformly Most Powerful tests, Likelihood Ratio tests.

Testing of hypothesis: Null and alternative hypothesis, level of significance, Type I and Type II errors, critical region and p-value, test for proportion-one and two samples, test for mean-one and two samples, test for variance-one and two samples, test for Goodness-of-fit.


Suggested Readings:

1. Probability & Statistics For Engineers & Scientists, Ninth Edition, Walpole, Myers, Myers, Ye

Online Reading/Supporting Material

10. Database Management System

Objective: The prime objective of this course is to teach practical, but generic, skills which can be applied to a vast majority of contemporary database management systems (DBMSs).


Relational Model Catalog-Types, Keys, Relational Algebra- Fundamental operations, Structured Query Language, Data Definition Language, Queries in sql. Basic set, Aggregate functions, Null Values, Nested Sub queries, Views

Integrity and Security Triggers, Missing Information, Introduction to distributed and client /server databases.

Suggested Readings:
11. Queueing and Reliability Theory

Objective: This course aims to introduce topics in queueing (waiting lines) theory and Reliability analysis.

Queueing Systems

General concepts of a queueing system, measures of performance, arrival and service processes, single and multiple server models, channels in parallel and in series with limited and unlimited queues, Little’s formula, Queues with finite waiting room, Queues with impatient customer (Balking and reneging), Markovian queues- M/M/1 with finite and infinite waiting space, M/M/C, Birth and death queueing systems, Finite Source

Reliability and availability

Basics of reliability, hazard rate and MTBF, classes of life distribution, Reliability of series, parallel, standby, k out of n, Series-Parallel, Parallel-series configurations and bridge structure. Reliability and Availability models.

Suggested Readings:


Practical/Lab to be performed on a computer using OR/Statistical packages

LIST OF PRACTICALS
1. To determine the performance measures for M/M/1 queuing model.
2. To determine the performance measures for M/M/1/N queuing model.
3. To determine the performance measures for M/M/C/∞ queuing model.
4. To determine the performance measures for M/M/C/N queuing model.
5. Calculation of hazard rate, MTBF for series & parallel system.
6. Calculation of hazard rate, MTBF for Mixed configuration.
12. Optimization - II

**Objective:** To equip students with practical implication of theoretical methods studied under Optimization theory and to introduce multi-objective decision making techniques.


**Suggested Readings**


13. Decision and Game Theory

Objective: The objective of the course is to introduce Decision and Game Theory concepts for scientific study of strategic decision making.

Decision making without and with experimentation. Decision Trees. Utility theory. Decision under risk: expected value, expected value - variance, aspiration - level, and most likely future criteria. Decision under uncertainty: Laplace and Minimax (Maxmin) criteria.


Suggested Readings

14. Scheduling Techniques

Objective: The paper focuses on the various types of scheduling problems and techniques that can be employed to solve concerned problems. The aim is to equip the students with the tools to provide optimal solution for real world problems.


Sequencing problem: Introduction to Sequencing problem. Flow shop problem: Processing \( n \) jobs through \( 2, 3 \) and \( m \) machines. General \( n/m \) job-shop problem.

References /Suggested Readings:


Practical/Lab to be performed on a computer using OR/Statistical packages

List of Practicals

1. Shortest Path Problem using Dijkstra’s algorithm
2. Minimal Spanning Tree
3. Project planning (Deterministic case-CPM).
4. Project planning (Probabilistic case-PERT).
5. Crashing of the Project.
Discipline Specific Elective Papers in Operational Research

1. Logistics and Supply Chain Management

Objective: Introduce the analytic model based approach for solving logistics and supply chain problems

Supply Chain management – introduction and development, objectives and needs, importance, value chain, components of supply chain, participants in supply chain and customer focus, global applications.

Logistics- Origin and Definition, Logistics Management, types of logistics, Transportation- role of transportation in logistics, Application of IT in logistics. Warehousing – nature and importance, warehousing functions, layout and design of warehouse, role of packaging.

Inventory – Control of Inventory, Distribution Resource Planning (DRP), Material Requirement Planning(MRP-I), Manufacturing Resource Planning(MRP-II).

Supply chain performance drivers, key enablers in supply chain improvement, Outsourcing and 3PLs, Fourth party logistics, Coordination and Lack of Supply chain management and Bullwhip effect in supply chain, Benchmarking.

References /Suggested Readings:

3. V. V. Sople, Supply Chain Management: Text and Cases. Pearson Education India (2011).
2. Quality Management

Objective: The objective is to understand the Quality Management concept and principles and the various tools available to achieve Total Quality Management also to understand the statistical approach for quality control.


Meaning and significance of statistical process control and statistical product control. Quality Improvement Tools- Pareto Chart, Cause effect diagram, Construction of Control charts for variables and attribute.

Acceptance sampling plans, process capability meaning – significance and measurement, six sigma-features, enablers, goals, concept of process capability, DMAIC and DMADV.


References /Suggested Readings:

3. Managerial Economics

Objectives: The course in Managerial Economics attempts to build a theoretical foundation in analytical nature of economics.


Meaning and Determinants of Demand. Demand Function, Law of Demand Market Demand, Elasticity of Demand, Types and Measurement of Elasticity, Demand Forecasting. Meaning, Significance and Methods of Demand Forecasting.


References /Suggested Readings:

4. Project Management

Objective: The course offers a practical approach to managing projects, focusing on organizing, planning, and controlling the efforts of the project.

Basics of project management, feasibility and technical analysis: materials and equipment, project costing & financing, financial aspects, cost benefit analysis, success criteria and success factors, risk management

Mathematical models: project selection, project planning, cost-time trade-off, resource handling/leveling.

References /Suggested Readings:

5. Business Data Analysis

Objective: To provide the key methods of predictive analytics and Business Data Analysis concepts.

Business fundamentals, Importance of business data analytics, Evolution of business data analytics, Scope of business data analytics

Data processing and data warehousing

Data Management, Data Summarization, Data Cleaning, Data integration, Data reduction, Data warehousing, OLAP vs. OLTP, ROLAP, MOLAP

Techniques for data analysis

Association rule mining- Market Basket Analysis, Prediction Analysis, Unsupervised and supervised learning.

References /Suggested Readings:

1. A practitioner's guide to business analytics: Using Data Analysis Tools to Improve Your Organization’s Decision Making and Strategy, Randy Bartlett
3. Introduction to Data Mining, Pang-Ning Tan, Michael Steinbach and Vipin Kumar, Pearson Education, 2007
6. Time Series and Econometrics

Objective: The objective of this course is to equip students with the tools necessary for economic time series data and introduce applied econometric techniques

Time Series


Econometrics

An introduction to econometrics, two-variable Regression Analysis, multiple regression analysis, Multicollinearity, Heteroscedasticity, Autocorrelation, lag models

References /Suggested Readings:

1. Basic Econometrics, 5th edition, Damodar Gujarati
2. Econometric methods, 4th edition, J Johnston
7. Quantitative Marketing and Finance

Objective: The objective of the course is to introduce the basic concepts in Marketing and Financial Management and mathematical models for the decision making.

Basic concepts of marketing and its role in business. Marketing decisions, Mathematical models in marketing: joint optimization of price and promotional efforts, media allocation of advertisement, brand switching analysis.

Introduction to basic financial management concepts: financial analysis and planning, short term and long term financial planning. Mathematical models: working capital, capital budgeting, inventory management and cash management problems.

References /Suggested Readings:

8 Project Work / Industrial Training
Ability Enhancement Electives (skill based)

1. Data Analysis

Objective: To enable the student to explore with the real data set and analytical tools.

Data Collection:- sources and methods of data collection, questionnaire design, sampling-sample size, sampling distribution, methods of sampling, sampling errors.


Basic concept of inference:-

Testing of hypothesis for single and two (mean and proportion), ANOVA (one and two way) and interpretation.

Suggested Readings:

2. Numerical Methods

Objective: This course provides coverage of key numerical methods to solve practical mathematical problems


References /Suggested Readings:

3. Operational Research Applications

**Objective:** To make the student understand the real life applications of Operational Research and their solutions using various O.R. packages.

Media allocation problem, Cargo Loading Problem, Production Scheduling Problem, Wood cutting problem, School bus routing problem, Simulation, Knapsack problem, Set Covering Problem, Fixed Charge Transportation Problem, Project Selection Problem using OR Software’s.

**References /Suggested Readings:**


4. Introduction to Information Technology

Objective: The objective is to obtain understanding of the concepts of Information Technology and its applications and also become familiar with the use of Information Technology tools.


Internet: Internet Architecture — Types-Network Security-Internet applications- Internet address-domain name- E-mail

References/Suggested Readings:

1. Introduction to Information Technology Pelin Aksoy, Laura DeNardis,Cengage Learning India Private Limited, First Indian Reprint 2008.
Generic Elective / Interdisciplinary

1: Essentials of Operational Research and Linear programming

Objective: The objective of the paper is to introduce the basic concepts of Operational Research and Linear programming to the students.

Origin & Development of OR, Different Phases of OR study, Methodology of OR, Scope and Limitations of OR, OR in decision making, Applications of OR.

Linear Programming: Linear combination of vectors, Linearly independent / dependent vectors, Basis of a vector space, Convex set and its properties, Extreme points.

General Linear programming problem, Standard and canonical form of LPP, Formulation of LPP, Graphical solution, Simplex method, Artificial variable techniques- Two Phase Method; Charnes M Method, Special cases in LPP, Finding Inverse of a matrix using simplex method, Solving system of linear equations using simplex method.

Duality: Definition of the dual problem, Primal-dual relationships, Economic Interpretation of Duality, Dual simplex Method.

Sensitivity analysis: Shadow Price, Graphical and simplex method based approach for changes in cost and resource vector.

Text Book Readings:
2: Inventory Management

Objective: The aim of the paper is to introduce the basic concepts of inventory Management to the students.

Introduction to inventory systems, Different costs in inventory system, Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.

Deterministic continuous review models: Basic Economic order quantity (EOQ) model (with and without shortages), EOQ with finite supply (with and without shortages), EOQ with backorders, Determination of reorder point for all the models. Multi-item EOQ model with constraints, All-unit quantity discount model.

Probabilistic inventory models: Single period probabilistic inventory models with discrete and continuous demand.

Text Book Readings:


3. Network Models and Scheduling Techniques

Objective: This paper focuses on the various types of scheduling problems and techniques that can be employed to solve concerned problems.

Network optimization models: Basic concepts, Transportation problem: formulation as a linear programming problem, methods to find initial basic feasible solution (NWCM, LCM, VAM) and optimal solution (MODI )


Project Scheduling: Network representation of project, Project scheduling :critical path method and PERT, Types of Floats, Crashing : Time and cost trade-off.

Text Book Readings:
4. Integer Programming and Theory of Games

Objective: To enrich the knowledge of students with advanced techniques of linear programming problem along with real life applications.

Integer Programming Problem (IPP): Pure and mixed IPP, Methods for solving IPP: Branch & Bound method, Gomory’s cutting plane method. Applications of IPP.

Theory of Games: Introduction to Game theory, Formulation of two-person zero-sum rectangular game; Solution of rectangular games with saddle points; dominance principle; rectangular games without saddle point – mixed strategy, Graphical, algebraic and linear programming solution of m x n games.

Text Book Readings:
5. Queuing and Reliability Theory

**Objective:** The aim of the paper is to impart to the students the basics of queuing and reliability theory. The paper also attempts to provide the real life applications for the same.

**Queuing Theory:** Basics of queuing system, Kendall's notation, performance measures, Little's formula, Birth-death process, Markovian models: - Single server with finite and infinite capacity, multi servers’ queues.

**Reliability Theory:** Basics of reliability, hazard rate, mean time before failure (MTBF), failure time distribution functions, reliability of configurations- series, parallel, mixed configuration, k out of n system and standby system, Reliability and Availability models, Time dependent and independent Replacement policies, Concepts and definitions of Preventive Maintenance, Corrective Maintenance and Age Replacement.

**Text Book Readings:**


6. Optimization Techniques

Objective: The paper is the sub-field of Optimization dealing with problems that occur frequently in mathematics/economics and finance. The paper also gives to the students an overview of the class of problems with multiple goals.

Non-Linear Programming: Convex function and its properties, basics of NLP, Method of Lagrange multiplier, Karush-Kuhn-Tucker optimality conditions, Quadratic Programming: Basic Concepts, Wolfe’s method, Beale’s method

Dynamic Programming: Multistage decision processes, Recursive nature of computations, Forward and Backward recursion, Bellman’s principle of optimality, Selective dynamic programming applications involving additive and multiplicative separable returns for objective as well as constraint functions, Problem of dimensionality.

Goal Programming: Basics of Goal programming, Weighted and pre-emptive goal programming, Formulation of Goal programming problem and graphical solution.

Text Book Readings: