

**UNIVERSITY OF DELHI**

**DEPARTMENT OF OPERATIONAL RESEARCH**

**COURSE NAME: BSc (Hons.) Operational Research**

**(SEMESTER -I)**

based on

Undergraduate Curriculum Framework 2022 (UGCF)  
(Effective from Academic Year 2022-23)



University of Delhi

**Course name: B Sc (Hons.) Operational Research**

Course Title	Nature of the Course	Total Credits	Components			Eligibility Criteria/ Prerequisite	Contents of the course and reference is in
			Lecture	Tutorial	Practical		
Introduction to Operational Research and Linear Programming	DSC-01	4	3	0	1	Class XII Pass with Mathematics as a subject	Annexure-I
Linear Algebra and Calculus	DSC-02	4	3	1	0	Class XII Pass with Mathematics as a subject	Annexure-II
Production and Inventory Management	DSC-03	4	3	0	1	Class XII Pass with Mathematics as a subject	Annexure-III
Introduction to Operational Research and Linear Programming	GE-01	4	3	0	1	Class XII Pass with Mathematics as a subject	Annexure-IV

# **ANNEXURE-I**

## **DSC - 01. Introduction to Operational Research and Linear Programming**

### **Course Objectives:**

*The Objective of the paper is to introduce the basic concepts of Operational Research and Linear Programming to the students.*

### **Course Learning Outcomes:**

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.

### **Contents:**

**Unit I:** Basics of Operational Research: Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real Life Problems.

**Unit II:** Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Unit III:** Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Unit IV:** Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

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### **Reference/Suggested Readings:**

- Hadley, G. (2002). *Linear programming*. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). *Linear Algebra*. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). *Introduction to operations research- concepts and cases* (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). *Operations research - An Introduction* (10th ed.). Pearson Education.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (i) Unbounded solution.
  - (ii) Infeasible solution.
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M 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 solutions.
6. Solution to linear programming problem through revised simplex method.

**Teaching Plan:**

**Week 1-3:** Basics of Operational Research: Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Modelling of Real Life Problems.

**Week 4-5:** Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method.

**Week 6-8:** Concepts of Basis and Basic Feasible solution, Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Week 9-11:** Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Week 12-13:** Degeneracy in Linear Programming, Charnes' Perturbation method.

**Week 14-15:** Revised Simplex method-Standard form-I and Standard form-II.

**Facilitating the achievement of Course Learning Outcomes**

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning, origin and development of Operational Research. (ii) Understand the scope and development of Operational	(i) While introducing each topic some examples will be laid out and discussed with the students	<ul style="list-style-type: none"><li>• Class discussion and presentations</li><li>• Weekly Assignments</li></ul>

	Research (iii) Mathematical modelling of real world problems.	encouraging them to discover the relevant concepts.	<ul style="list-style-type: none"> <li>• Student presentation</li> <li>• Mid-Term examination,</li> <li>• Group activities involving students to solve real-world problems using solver</li> <li>• Hold both announced and unannounced quizzes</li> <li>• End-term examination</li> </ul>
2.	(i) Formulate real-world problems as linear programming model.  (ii) Describe the theoretical workings of the graphical method for linear programming and demonstration by hand and solver.  (iii) Explain the theoretical foundations of various topics related to linear programming modelling.	(ii) Give extensive examples during lectures.  (iii) Give periodic assignments.  (iv) Encourage students to participate in class discussion.	
3.	(i) Describe the theoretical workings of the simplex method for linear programming and demonstration of the iterations by hand and solver.	(v) Encourage students to give short presentation.  (vi) Encourage students to apply concepts to solve real-world problems.	
4.	(i) Explain the concept of Degeneracy in Linear Programming and a method for resolving it.  (ii) Explain the revised simplex algorithm and its economic importance over simplex algorithm.		

# ANNEXURE-II

## DSC-02. Linear Algebra and Calculus

### Course Objectives:

*The objective of the paper is to provide a platform for introduction to linear algebra and calculus. This course will give the rudimentary idea of Mathematics to be useful in the course of Operational Research.*

### Course Learning Outcomes:

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of key concepts of Linear Algebra and Calculus and their role in Operations Research.
- Describe the basic concepts of matrices and system of linear equations.
- Demonstrate the understanding of linear combinations, Linear span, Basis and Eigen values and related theorems.
- Explain the fundamentals of Limit, Continuity and Differentiability.
- Demonstrate the utility of Maxima, Minima and Lagrangian function.

### Contents:

**Unit I:** 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.

**Unit II:** Vector Spaces: Definition, Sub-spaces, Linear Combinations, Linear independence and dependence of vectors, Linear Span, Basis & Dimension, Eigen Values, Eigen Vectors, Characteristic Polynomial, Diagonalization, Cayley Hamilton Theorem.

**Unit III:** Calculus: Functions of one variable: Limit, continuity, Differentiability, Intermediate value theorem, Rolle's Theorem, Mean value theorem, Cauchy's mean value theorem, Taylor series, Maclaurin series.

**Unit IV:** Concepts of Maxima and Minima, Lagrangian function and its geometric interpretation.

### Reference/Suggested Readings:

- Lay, D. C. (2015). *Linear Algebra and its Applications* (5<sup>th</sup> ed.). Pearson.
- Lang, S. (2004). *Linear Algebra* (3<sup>rd</sup> ed.). Springer.
- George, B. T. Jr. and Finney, R. L. (2010). *Calculus and Analytic Geometry* (9th ed.). Pearson.
- Strang, G. (2016). *Introduction to Linear Algebra* (5<sup>th</sup> ed.). Wellesey-Cambridge Press.

### Teaching Plan:

**Week 1-2:** Matrices & System of Linear Equations: Matrix Algebra, Types of Matrices, Elementary row operations on a Matrix.

**Week 3-4:** Echelon form of a Matrix, Rank of a Matrix, Inverse of a matrix, Solution of System of Homogeneous & Non-Homogeneous Equations.

**Week 5-6:** Vector Spaces: Definition, Sub-spaces, Linear Combinations, Linear independence and dependence of vectors, Linear Span, Basis & Dimension.

**Week 7-8:** Eigen Values, Eigen Vectors, Characteristic Polynomial, Diagonalization, Cayley Hamilton Theorem.

**Week 9-10:** Calculus: Functions of one variable: Limit, continuity, Differentiability.

**Week 11-12:** Intermediate value theorem, Rolle's Theorem, Mean value theorem, Cauchy's mean value theorem, Taylor series, Maclaurin series.

**Week 13-15:** Concepts of Maxima and Minima, Lagrangian function and its geometric interpretation.

### Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning of matrices and system of linear equations. (ii) Explain various operations on matrices and solutions of systems of equations.	(i) While introducing each topic some examples will be laid out and discussed with the students encouraging them to discover the relevant concepts.	<ul style="list-style-type: none"> <li>• Class discussion and presentations</li> <li>• Weekly Assignments</li> <li>• Student presentation</li> <li>• Mid-Term examination,</li> <li>• Group activities involving students to solve real-world problems using solver</li> <li>• Hold both announced and unannounced quizzes</li> <li>• End-term examination</li> </ul>
2.	(i) Describe the basic concepts of vector spaces. (ii) Explain the theoretical foundations of various topics related to vector spaces.	(ii) Give extensive examples during lectures.	
3.	(i) Explain the fundamentals of limit, continuity and differentiability. (ii) Describe the theoretical framework and utility of various theorems in Calculus.	(iii) Give periodic assignments. (iv) Encourage students to participate in class discussion. (v) Encourage students to give short presentation.	
4.	(i) Explain the concepts of Maxima and Minima in calculus. (ii) Describe the utility of Lagrangian function and its geometrical interpretation.	(vi) Encourage students to apply concepts to solve real-world problems.	

# **ANNEXURE-III**

## **DRC-03. Production and Inventory Management**

### **Course Objectives:**

*The objective of this course is to introduce fundamental concepts in production and inventory management and at the same time, develop the students' modelling and analytical skills.*

### **Course Learning Outcomes:**

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of key concepts of Production and Inventory management and its role in various organizations.
- Apply selective inventory control techniques and understand its significance.
- Determine optimal order quantity for various deterministic and probabilistic inventory models.
- Understand quantity discount models in inventory management.
- Formulate and develop Production Planning and Scheduling models.
- To apply and extend production and inventory models to analyse real world systems.

### **Contents:**

**Unit I:** Introduction to Production and Inventory Management, Different types of costs in inventory system, Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.

**Unit II:** Deterministic continuous review models: Economic order quantity (EOQ) model with and without shortages, Finite replenishment rate Inventory models without and with planned shortages. Determination of reorder point, Quantity discount models.

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

**Unit IV:** 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).

### **Reference/Suggested Readings:**

- Axsäter, S. (2015). *Inventory control* (3rd Edition). Springer.
- Buffa, Elwood S., & Sarin, Rakesh, K. (2009). *Modern Production/Operations Management* (8<sup>th</sup> ed.). Wiley, India.
- Hadley, G., & Whitin, T. M. (1963). *Analysis of inventory systems*. Prentice-Hall.

- Heizer, J., & Render, B. (2011). *Operations Management* (10th ed.). Pearson's Publication.
- Johnson, L.A., & Montgomery, D.C. (1974) *Operations Research in Production Planning, Scheduling and Inventory Control*. Wiley, New York.
- Naddor, E. (1966). *Inventory Systems*. Wiley.
- Silver, E. A., Pyke, D. F., & Peterson, R. (1998). *Inventory management and production planning and scheduling* (3rd ed.). Wiley.
- Waters, D. (2008). *Inventory control and management*. (2nd ed.). John Wiley & Sons.

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

1. Problems based on selective inventory classification. (ABC and FNS analysis)
2. To find optimal inventory policy for EOQ model.
3. To find optimal inventory policy for EOQ model with finite supply.
4. To find optimal inventory policy for EOQ model with backorders.
5. To solve all units quantity discounts model.
6. To solve Incremental quantity discount model
7. To find optimal inventory policy for Probabilistic inventory model with discrete demand.
8. To find optimal inventory policy for Probabilistic inventory model with continuous.
9. Solution of procurement/production scheduling model.

### **Teaching Plan:**

**Week 1-3:** Introduction to Inventory Management, Concepts and problems in Inventory Systems, various forms and functional role of Inventory, different types of costs in inventory system. Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.

**Week 4-6:** Formulation and solution of Economic order quantity (EOQ) models with and without lead time, and with and without shortages. Determination of reorder level.

**Week 7-8:** Finite replenishment rate Inventory models without and with planned shortages. Determination of reorder level.

**Week 9-10:** Inventory models with all units quantity discount, and Incremental quantity discount.

**Week 11-12:** Single period probabilistic inventory models with discrete and continuous demand.

**Week 13-15:** 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).



### Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning of Production and Inventory management, various forms and functional role of Inventory. (ii) Understand different types of costs in inventory systems. (iii) Apply various Selective inventory control techniques to classify inventory items into broad categories.	(i) While introducing each topic some examples will be laid out and discussed with the students encouraging them to discover the relevant concepts.	<ul style="list-style-type: none"> <li>• Class discussion and presentations</li> <li>• Weekly Assignments</li> <li>• Student presentation</li> <li>• Mid-Term examination,</li> <li>• Group activities involving students to solve real-world problems using solver</li> <li>• Hold both announced and unannounced quizzes</li> <li>• End-term examination</li> </ul>
2.	(i) Calculate the Economic Order Quantity (EOQ) for various Deterministic Inventory models without and with lead time. (ii) Compute the Reorder Level (ROL) and to determine time of replenishment with known and unknown patterns of demand for inventory items. (iii) Understand quantity discount models and determine the EOQ for the same.	(ii) Give extensive examples during lectures.  (iii) Give periodic assignments.  (iv) Encourage students to participate in class discussion.	
3.	(i) Understand probabilistic inventory models. (ii) Develop Single period probabilistic inventory models with discrete and continuous demand.	(v) Encourage students to give short presentation.  (vi) Encourage students to apply	
4.	(i) Introduction to Production Planning and Scheduling, Aggregate production plan (ii) Formulation of lot size production problem: Wagner and	concepts to solve real-world problems.	

	<p>Whitin algorithm.</p> <p>(iii) Understand the basic concepts of Just-in-Time (JIT) and Material Requirement Planning (MRP).</p>		
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# **ANNEXURE-IV**

## **GE 1. Introduction to Operational Research and Linear Programming**

### **Course Objectives:**

*The Objective of the paper is to introduce the basic concepts of Operational Research and Linear Programming to the students.*

### **Course Learning Outcomes:**

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.

### **Contents:**

**Unit I:** Basics of Operational Research: Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real Life Problems.

**Unit II:** Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Unit III:** Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Unit IV:** Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

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### **Reference/Suggested Readings:**

- Hadley, G. (2002). *Linear programming*. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). *Linear Algebra*. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). *Introduction to operations research- concepts and cases* (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). *Operations research - An Introduction* (10th ed.). Pearson Education.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (iv) Unbounded solution.
  - (v) Infeasible solution.
  - (vi) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method
  - (v) Unrestricted variables.
  - (vi) Unbounded solution.
  - (vii) Infeasible solution.
  - (viii) Alternative or multiple solutions.
7. Solution to linear programming problem through revised simplex method.

**Teaching Plan:**

**Week 1-3:** Basics of Operational Research: Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Modelling of Real Life Problems.

**Week 4-5:** Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method.

**Week 6-8:** Concepts of Basis and Basic Feasible solution, Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Week 9-11:** Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Week 12-13:** Degeneracy in Linear Programming, Charnes' Perturbation method.

**Week 14-15:** Revised Simplex method-Standard form-I and Standard form-II.

**Facilitating the achievement of Course Learning Outcomes**

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning, origin and development of Operational Research.	(i) While introducing each topic some examples will be laid	<ul style="list-style-type: none"><li>• Class discussion and presentations</li></ul>

	<p>(ii) Understand the scope and development of Operational Research</p> <p>(iii) Mathematical modelling of real world problems.</p>	<p>out and discussed with the students encouraging them to discover the relevant concepts.</p>	<ul style="list-style-type: none"> <li>• Weekly Assignments</li> <li>• Student presentation</li> <li>• Mid-Term examination,</li> <li>• Group activities involving students to solve real-world problems using solver</li> <li>• Hold both announced and unannounced quizzes</li> <li>• End-term examination</li> </ul>
2.	<p>(i) Formulate real-world problems as linear programming model.</p> <p>(ii) Describe the theoretical workings of the graphical method for linear programming and demonstration by hand and solver.</p> <p>(iii) Explain the theoretical foundations of various topics related to linear programming modelling.</p>	<p>(ii) Give extensive examples during lectures.</p> <p>(iii) Give periodic assignments.</p> <p>(iv) Encourage students to participate in class discussion.</p>	
3.	<p>(i) Describe the theoretical workings of the simplex method for linear programming and demonstration of the iterations by hand and solver.</p>	<p>(v) Encourage students to give short presentation.</p> <p>(vi) Encourage students to apply concepts to solve real-world problems.</p>	
4.	<p>(i) Explain the concept of Degeneracy in Linear Programming and a method for resolving it.</p> <p>(ii) Explain the revised simplex algorithm and its economic importance over simplex algorithm.</p>		