Proposed Syllabus and Scheme of Examination

for

B. Sc. (Honours) Operational Research

Submitted

to

University Grants Commission
New Delhi

under

Choice Based Credit System

May 2015

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 scare 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)

	CORE COURSE (14)	Ability Enhancement Compulsory Course (AECC) (2)	Ability Enhancement Elective Course (AEEC) (2) (Skill	Elective: Discipline Specific DSE (4)	Elective: Generic (GE) (4)
I	Introduction to Operational Research and Linear Programming (Theory+ Practical) Mathematics – I	(English/MIL Communication) /Environmental Science			GE-1
II	Advanced Linear Programming(Theory+ Practical) Statistics – I	Environmental Science/ (English/MIL Communication)			GE-2
III	Optimization – I(Theory+ Practical) Mathematics – II Object Oriented Programming(Theory+ Practical)		OR-AEE-1		GE-3
IV	Production and Inventory Management(Theory+ Practical) Statistics – II Database Management System		OR-AEE-2		GE-4
V	Queueing and Reliability Theory(Theory+ Practical) Optimization – II			OR-DSE-1 OR-DSE -2	
VI	Decision Analysis and Game Theory Scheduling Techniques(Theory+ Practical)			OR-DSE -3 OR-DSE -4	

SEMESTER I			
Paper Code	**COURSE NAME**		**Credits**
OR-AEC-1	(English/MIL Communication) /Environmental Science	Ability Enhancement	2
OR-C-101	Introduction to Operational Research and Linear Programming	Core Discipline	4
	Practical/OR Lab		2
OR-C-102	Mathematics – I	Core Discipline	5
	Tutorial		1
OR-GE-1	Any one from the List of **Generic Elective / Interdisciplinary Courses** from other Subjects	Generic Elective / Interdisciplinary	4/5
	Practical/Tutorial		2/1
SEMESTER II			
OR-AEC-2	Environmental Science/ (English/MIL Communication)	Ability Enhancement	2
OR-C-201	Advanced Linear Programming	Core Discipline	4
	Practical/OR Lab		2
OR-C-202	Statistics – I	Core Discipline	5
	Tutorial		1
OR-GE-2	Any one from the List of **Generic Elective / Interdisciplinary Courses** from other Subjects	Generic Elective/Interdisciplinary	4/5
	Practical/Tutorial		2/1
SEMESTER III			
OR-C-301	Optimization – I	Core Discipline	4
	Practical/OR Lab		2
OR-C-302	Mathematics – II	Core Discipline	5
	Tutorial		1
OR-C-303	Object Oriented Programming	Core Discipline	4
	Practical/OR Lab		2
OR-AEE-1	Any one from the List of **Ability Enhancement Electives**	Skill Enhancement Electives	2
OR-GE-3	Any one from the List of **Generic Elective / Interdisciplinary Courses** from other Subjects	Generic Elective / Interdisciplinary	4/5
	Practical/Tutorial		2/1
SEMESTER IV			
OR-C-401	Production and Inventory Management	Core Discipline	4
	Practical/OR Lab		2
OR-C-402	Statistics – II	Core Discipline	5
	Tutorial		1
OR-C-403	Database Management System	Core Discipline	4
	Practical/OR Lab		2
OR-AEE-2	Any one from the List of **Ability Enhancement Electives**	Skill Enhancement Electives	2
OR-GE-4	Any one from the List of **Generic Elective / Interdisciplinary Courses** from other Subjects	Generic Elective / Interdisciplinary	4/5
	Practical/Tutorial		2/1

SEMESTER V			
OR-C-501	Queueing and Reliability Theory	Core Discipline	4
	Practical/OR Lab		2
OR-C-502	Optimization – II	Core Discipline	5
	Tutorial		1
OR-DSE-1	Any one from the List of **Discipline Specific Elective(DSE)**	Discipline Specific Elective	5
	Tutorial		1
OR-DSE-2	Any one from the List of **Discipline Specific Elective(DSE)**	Discipline Specific Elective	5
	Tutorial		1
SEMESTER VI			
OR-C-601	Decision Analysis and Game Theory	Core Discipline	5
	Tutorial		1
OR-C-602	Scheduling Techniques	Core Discipline	4
	Practical/OR Lab		2
OR-DSE-3*	Any one from the List of **Discipline Specific Elective(DSE)**	Discipline Specific Elective	5
	Tutorial		1
OR-DSE-4*	Any one from the List of **Discipline Specific Elective(DSE)**	Discipline Specific Elective	5
	Tutorial		1

*** Project Work/Industrial Training will be offered in the Sixth Semester.**

Core Papers (Credit: 06 each) (14 papers)

OR-C -101. Introduction to Operational Research and Linear Programming (Theory+ Practical)
OR-C -102. Mathematics – I
OR-C -201. Advanced Linear Programming (Theory+ Practical)
OR-C-202. Statistics – I
OR-C -301. Optimization – I (Theory+ Practical)
OR-C -302. Mathematics – II
OR-C -303. Object Oriented Programming (Theory+ Practical)
OR-C -401. Production and Inventory Management (Theory+ Practical)
OR-C -402. Statistics – II
OR-C -403. Database Management System
OR-C -501. Queueing and Reliability Theory (Theory+ Practical)
OR-C -502. Optimization – II
OR-C -601. Decision Analysis and Game Theory
OR-C -602. 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 Papers (GE) (Credit: 06 each) (04 papers of any discipline to be selected from other Departments/Disciplines)

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

1. Data Analysis
2. Operational Research Applications
3. Introduction to Information Technology
4. Numerical Methods

Generic Elective Papers (GE) (Credit: 06 each) (Any four to be offered to other Departments / Disciplines)

1. Introduction to 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

Core Papers in Operational Research

OR-C-101. 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.

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 Modeling of Real Life 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.

Linear Programming Problem Formulation, solution by Graphical Method, Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charnes-M Method, Degeneracy, Theory of Duality, Dual-simplex method.

References /Suggested Readings:

1. G. Hadley: Linear Programming. Narosa, Reprint, 2002.
2. G. Hadley: Linear Algebra, Narosa, Reprint, 2002.
3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
4. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
5. F.S. Hillier. G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata Mc-Graw Hill, 2010.

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.
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. Problems based on Dual simplex method.

OR-C-102. Mathematics - I

Objective: 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 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, Cauchy's mean value theorem. Taylor series, Maclaurin series.

Reference/Suggested Readings:

1. David C. Lay: Linear Algebra and its Applications, 3rd Edition, Pearson Education, Indian Reprint, 2007.
2. Serge Lang, Linear Algebra, 3rd Edition, Springer, 2000.
3. George B. Thomas JR., Ross L. Finney: Calculus and Analytic Geometry, Pearson Education (Singapore), 2001.
4. Gilbert Strang: Introduction to Linear Algebra, Fourth Edition, Wellesey-Cambridge Press/Cengage Learning, 2009.

OR-C-201. Advanced Linear Programming

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

Transportation problem (TP) and its formulation. finding basic feasible solution of TP using North-West Corner Rule, Least Cost and Vogel's Approximation Method, MODI method for finding optimal solution for TP, Assignment problem and its formulation, Hungarian method for solving Assignment problem, Transhipment and Travelling salesmen problem.

Revised Simplex Method, Bounded Variable linear programming problem, Interior point algorithm for linear programming problem.

Introduction to linear integer programming, Branch and Bound Technique, Gomory's Cutting Plane Algorithm for pure and mixed linear integer programming problem, E-Bala's Algorithm for 0-1 programming problem, Real life applications of linear Integer Programming Problem.

References / Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
2. Wayne L. Winston and M. Venkataramanan: Introduction to Mathematical Programming: Applications and Algorithms, 4th edition, Duxbury Press, 2002.
3. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
4. G. Hadley: Nonlinear and Dynamic Programming, Addison-Wesley, 1964.

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

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.
6. Solution of Capital Budgeting Problem.
7. Solution of Fixed charge problem.

OR-C-202. Statistics-I

Objective: The objective is to introduce basic probability theory required in the courses of Operational Research.

Probability: Probability Axioms, Conditional Probability and Bayes' Theorem and its Applications.

Random Variables and Distributions, Expectation and Variance, Moment Generating Functions and Characteristic Function.

Multidimensional Random Variable: Conditional Expectation and Conditional Variance. Joint, Marginal and Conditional Distributions. Independent Random Variables. Limit Theorems.

Discrete Random Variables (Binomial, Poisson and Geometric). Continuous Random Variables (Normal, Exponential, Uniform and Gamma). Laws of Large Numbers. Central Limit Theorem.

Correlation and Regression: Karl Pearson's Coefficient of Correlation, Lines of regression.

References / Suggested Readings:

1. Sheldon Ross: Introduction to Probability Models, 10th Edition, Academic Press/Elsevier, 2012.
2. Jay L. Devore: Probability and Statistics for Engineering and the Sciences, 8th Edition, Cengage Learning, 2012.
3. R.V. Hogg, A.T. Craig, and J.W. Mckean: Introduction to Mathematical Statistics, 6th Edn., Pearson Education, 2009.
4. William Feller: An Introduction to Probability Theory and Its Applications, 3rd Edition**.** Wiley India, 2009.

Online Reading/Supporting Material

1. www.openintro.org/stat/down/OpenIntroStatFirst.pdf

OR-C-301. 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.

Convex functions and their properties. Unconstrained and constrained optimization problems. Fritz-John and Karush-Kuhn-Tucker optimality conditions. Quadratic Programming: Wolfe's and Beale's method. Applications of Quadratic programming. Dorn's Duality for Quadratic programming problem.

Linear and Quadratic Programming Complementary Pivoting Algorithms. Steepest Ascent and Descent Method. Feasible Direction Method. Separable Programming. Linear Fractional Programming.

References / Suggested Readings:

1. M. S. Bazara, H. D. Sherali, C. M. Shetty: Nonlinear Programming-Theory and Algorithms. Wiley, 3rd Edition, 2006.
2. A. Antoniou, Wu-Sheng Lu: Practical Optimization- Algorithms and Engineering Applications, Springer, 2007.
3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
4. Wayne L. Winston and M. Venkataramanan: Introduction to Mathematical Programming: Applications and Algorithms, 4th edition, Duxbury Press, 2002.
5. O. L. Mangesarian: Nonlinear Programming, McGraw Hill, New York, 1969. Reprint: SIAM Classics in Applied Mathematics 10, 1994, PhiIadelphia.
6. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Applications, Narosa Publishing House, 2009.
7. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
8. G. Hadley: Nonlinear and Dynamic Programming, Addison-Wesley, 1964.

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

1. To determine local/Relative optima of a given unconstrained problem.
2. Test whether the given function is concave/convex.
3. Test whether the given matrix is positive definite/negative definite/semi positive definite/ semi negative definite
4. Solution of optimization problems using Karush-Kuhn-Tucker conditions.
5. Solution of Quadratic programming problem by Wolfe's method.
6. Solution of Quadratic programming problem by Beal's method.

OR-C-302. Mathematics -II

Objective: This paper is designed to enrich the knowledge of students with understanding of key concepts of advanced calculus and differential equations.

Calculus on R^n: Functions of several variables: Limits and continuity of functions of several variable, partial differentiation.

Differential equations: Order and degree of ordinary differential equation, Basic differential equations (Separable Method, Linear D.E.), Second order linear homogeneous differential equations with constant coefficients and Euler Cauchy form, Second order linear non-homogeneous differential equations using method of variation of parameters.

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:

1. Erwin Kreyszig: Advanced Engineering Mathematics, John Wiley & sons, 9th Edition, 2006.
2. S. L. Ross: Differential Equations, John Wiley and Sons, India, 2004.
3. George B. Thomas and Ross L. Finney: Calculus, 10th Edition, Addison-Wesley, 2000.

OR-C-303. Object Oriented Programming

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

Introduction to OOP: Procedure Oriented Programming, OOP Paradigm. Abstraction, Encapsulation, Data hiding, Inheritance, Polymorphism.

Introduction to C++: Identifier and keywords, Constants, Operators, Type Conversion, Variable Declaration, Expressions, Statements, Manipulators. Input and Output Statements, Stream I/O. Arrays, 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, Exceptions handling.

Inheritance: Single, Multiple, and Multi level. Polymorphism: function overloading and Operator overloading. Files and Streams. String processing.

Reference/Suggested Readings:

1. Herbert Schildt: The Complete Reference C++, Tata McGraw-Hill, 2001
2. Deitel and Deital: C++ How to program, Pearson Education, 2001.
3. Robert Lafore: Object Oriented Programming in Turbo C++, Galgotia Publications, 1994.
4. BajaneStautrup: The C++ Programming Language, Addition,-Wesley Publication Co., 2001.
5. E. Balagurusamy: Object-Oriented Programming with C++, Tata McGraw-Hill, 2001.
6. B. A. Forouzan and R. F. Gilberg: Computer Science, A Structured Approach using C++ (2nd ed.), Indian Edition, Cengage Learning, 2004.

Practical/Lab 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 find the roots using the numerical methods.
5. Write a program to perform basic operations on matrices
6. Write a menu driven program for list operations: search, sort, max, and min for string arrays using different functions.
7. Write a program to find the EOQ with and without shortages.
8. Determine performance measures of M/M/1 and M/M/C models.
9. To find the reliability of parallel and series systems.

OR-C-401. 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, develop the students' modeling and analytical skills.

Introduction to inventory systems, 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).

Reference/Suggested Readings:

1. Donald Waters: Inventory Control and Management, John Wiley, 2010.
2. G. Hadley and T. M. Whitin: Analysis of Inventory Systems, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.
3. Buffa, Elwood S. and Sarin Rakesh K.: Modern Production/Operations Management, 8th Edition, Wiley India, 2009.
4. Edward A. Silver, David F. Pyke and Rein Peterson: Inventory Management and Production Planning and Scheduling, John Wiley, 3rd Edition, 1998.
5. Jay Heizer & Berry Render: Operations Management, Pearson's Publication, 10th edition, 2011.

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 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.

OR-C-402. 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.

Estimation: Point estimation: Properties of estimators; Unbiasedness, Consistency, Efficiency, Sufficiency, Minimum variance unbiased (MVU) Estimators, Factorization theorem, Cramer-Rao inequality, Method of moments, Maximum likelihood estimators.

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

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. Tests on independent and paired samples, Neyman-Pearson lemma, Uniformly Most Powerful tests, Likelihood Ratio tests.

Stochastic process: Classification, stationary process, Poisson Process, Markov Processes and Markov Chains, classification of states, Chapman Kolmogorov equations- Limiting and stationary distributions, Birth and death processes.

Reference/Suggested Readings:

1. Ronald E. Walpole, Raymond H. Myers, Sharon L. Myers and Keying E. Ye: Probability & Statistics For Engineers & Scientists, 9th Edition, 2011.
2. Irwin Miller, Marylees Miller: John E. Freund: Mathematical Statistics with Applications, 8th Edition, 2012.
3. J. Medhi: Stochastic Processes, New Age Science, 3rd Edition, 2009.
4. Sheldon Ross: Introduction to Probability Models, 10th Edition, Academic Press/Elsevier, 2012.

Online Reading/Supporting Material

1. www.openintro.org/stat/down/OpenIntroStatFirst.pdf

OR-C-403. Database Management System

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

Introduction, Purpose of Database System, View of Data, Data Models, Database Languages, Data Base System Architecture, ER model, Entity – Relationship diagram Introduction to relational databases, Constraints, keys, weak Entity set.

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.

Reference/Suggested Readings:

1. C. J. Date: An Introduction to Database Systems, 8th Edition, Addison Wesley, 2003.
2. H. F. Korth, A. Silberschatz, S. Sudarshan: Database System Concepts, McGraw Hill, 5th Edition, 2005.
3. Raghu Ramakrishnan: Database Management System, 3rd Edition, McGraw Hill, 2003.
4. Ramez Elmasri, Shamkant B. Navathe: Fundamentals of Database Systems, 4th Edition, Addison Wesley, 2003.

OR-C-501. 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.

Reference/Suggested Readings:

1. Donald Gross, John F. Shortle, James M. Thompson, Carl M. Harris: Fundamentals of Queueing Theory, 4th Edition, 2008.
2. J. Medhi: Stochastic Models in Queueing Theory, 2nd Edition, 2002.
3. K.S. Trivedi: Probability and Statistics with Reliability, Queuing and Computer Science Applications, 2nd Edition, Wiley, 2013.

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

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.

OR-C-502. Optimization - II

Objective: To equip students with practical implication of theoretical methods studied under Optimization theory. The course introduces Dynamic programming and multi-objective decision making techniques.

Introduction to Dynamic Programming. The recursive Equation Approach, Characteristics of Dynamic Programming, Developing Optimal decision Policy, Additive and Multiplicative Separable returns for objective as well as constraints functions. Discrete Dynamic programming Problems, Dynamic Programming Approach for solving Linear Programming Problem. Applications of Dynamic programming.

Introduction to Linear Multi-objective programming problem. Efficient and Properly Efficient solutions. Goal Programming. Types of Goal Programming. Graphical Solution method. Lexicographic, Weighted Sums and Interactive Methods for Solving Linear Multi-objective and Goal Programming Problems.

Reference/Suggested Readings:

1. R. E. Steuer: Multiple Criteria Optimization:Theory, Computation and Application (Wiley Series in Probability and Mathematical Statistics) Wiley, 1986.
2. M. Ehrgott: Multicriteria Optimization, Springer, Second Edition. 2005.
3. Ronald L. Rardin: Optimization in Operations Research, Prentice Hall, 1998.
4. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.

OR-C-601. 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.

Concepts of Game problem. Two- person zero-sum game. Pure and Mixed strategies. Saddle point and its existence. Fundamental Theorem of Rectangular games. Concept of Dominance. Dominance and Graphical method of solving Rectangular games. Relationship between rectangular game and Linear Programming Problem. Solving rectangular game by Simplex method.

Reference/Suggested Readings:

1. M. D. Resnik: Choices- An introduction to Decision Theory, University of Minnesota Press, 1987.
2. J. W. Pratt, H. Raiffa, R. Schlaifer: Introduction to Statistical Decision Theory, The MIT Press, 1995.
3. Martin Osborne, An Introduction to Game Theory, Oxford University Press, 2003.
4. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, - 2010.
5. F.S. Hillier and G.J. Lieberman : Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill. 2010.

OR-C-602. Scheduling Techniques

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

Network and Flows: Cut and flows in network, Maximal flow problems and solution techniques: Flow Augmenting Path Method, Labelling Method. Maximal Flow Minimal Cut Theorem. Shortest path problem: Dijkstra's Algorithm, Kruskal's Algorithm. Construction of Minimal Spanning Tree and its applications. Capacitated Transshipment model. Facility location models.

Project Scheduling: PERT and CPM with known activity times. Critical Path Analysis, Various types of floats. Probability considerations in PERT. Updating of PERT charts. Project crashing. Formulation of CPM as a linear programming problem. Resource leveling and resource scheduling.

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:

1. L. R. Ford, D. R. Fulkerson: Flows in Network, Princeton University Press, 1962.
2. M. S. Bazara, J. J. Jarvis, H. D. Sherali: Linear Programming and Network Flows, Wiley, 3rd Edition, 2004.
3. R. K. Ahuja, T. L. Magnanti, B. Orlin: Network Flows-Theory. Algorithm and Applications, Prentice Hall, NJ. 1993.
4. P. A. Jenson, W. J. Barnes: Network Flows Programming, John Wiley and Sons, 1980
5. S. E. Elmaghraby: Activity Networks, Project Planning, and Control, John Wiley and Sons, 1977.
6. J. D. Weist, F. K. Levy: A Management Guide to PERT/ CPM. 2nd Edition, PHI, 1967 (Reprint 2007).

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

1. To solve Shortest Path Problem using Dijkstra's algorithm
2. To find the Minimal Spanning Tree
3. To perform Project scheduling of a given project (Deterministic case-CPM).
4. To perform Project scheduling of a given project (Probabilistic case-PERT).
5. To perform Crashing of a given Project.
6. To solve Flow Shop Problem.

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:

1. S. Chopra and P. Meindl: Supply Chain Management, Upper Saddle River, N.J.: Pearson Prentice Hall, 2007.
2. D. Simchi-Levi: Designing and Managing the Supply Chain. McGraw-Hill Companies, 2005.
3. V. V. Sople: Supply Chain Management: Text and Cases. Pearson Education India, 2011.
4. A. R.. Ravindran, and D.P. Warsing Jr.: Supply Chain Engineering: Models and Applications. CRC Press, 2012.
5. A. Rushton, P. Croucher, and P. Baker: The handbook of logistics and distribution management: Understanding the supply chain. Kogan Page Publishers, 2014.

2. Quality Management

Objective: The objective is to introduce the Quality Management concept and principles and to understand the statistical approach for quality control.

Overview of quality, History of quality, Competitive Advantage, Industrial Perspective, Total Quality System, Taguchi Loss function concept. Juran's Triology.

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.

Introduction to ISO-9000 quality management systems and emerging standards. Benchmarking and Kaizen.

References /Suggested Readings:

1. P. Charantimath: Total Quality Management. New Delhi, India: Dorling KIndersley (India), 2011.
2. D. Besterfield: Total Quality Management. Englewood Cliffs, N.J.: Prentice Hall, 1995.
3. A. Godfrey and J. Juran: Total Quality Management. New York: McGraw-Hill, 1999.
4. D. Summers: Quality. Upper Saddle River, N.J.: Prentice Hall, 1997.
5. H. Rampersad: Total Quality Management. Berlin: Springer, 2000.
6. J. Oakland: Total Quality Management. Routledge, 2013.

3. Managerial Economics

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

Definition, Nature and Scope of Managerial Economics, Managerial Economics and decision-making. Uses and Significance of Managerial 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.

Production Function. Law of Variable Proportions. Law of Supply. Elasticity of Supply. Measurement of Elasticity of Supply. Costs of Production. Short run and long run costs. Economies of Scale. Cost estimation and cost forecasting. Breakeven analysis.

Pricing under various market forms: Perfect competition, Monopoly, Monopolistic Competition, Oligopoly, Price Discrimination.

Pricing Strategies and Methods, Cost plus Pricing, Marginal cost Pricing. Price Leadership, Transfer Pricing, Seasonal Pricing, Cyclical Pricing.

References /Suggested Readings:

1. Png, Ivan: Managerial Economics, 2nd edition, Malden, MA: Blackwell. 2002.
2. H.C. Peterson and W.C. Lewis: Managerial Economics, Prentice Hall of India Pvt. Ltd., New Delhi, 2001
3. Truett & Truett: Managerial Economics, John Wiley & Sons Inc., 8th Edition, 2004
4. G.S. Gupta: Managerial Economics, Tata McGraw Hills, New Delhi, 2011

4. Project Management

Objective: This course offers practical approach to managing projects, focusing on organizing, planning, and controlling the efforts in 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:

1. Ravi Ravindran: Operations Research and Management Science Handbook, CRC Press, 2008.
2. Harold Kerzner: Applied Project Management: Best Practices on Implementation, John Wiley & Sons, Inc., 2000.
3. J.C. Goodpasture: Quantitative Methods in Project Management, J Ross Publishing, Boca Raton, Florida, USA, 2003.
4. J.R. Meredith and S.J. Mantel Jr.: Project Management: A Managerial Approach, John Wiley,New York. 2004.

5. Business Data Analysis

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

Overview of Business data Analytics, 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. Randy Bartlett: A Practitioner's Guide to Business Analytics: Using Data Analysis Tools to Improve Your Organization's Decision Making and Strategy. McGraw Hill Professional, 2013.
2. Alex Berson and Stephen J. Smith: Data Warehousing, Data Mining & OLAP, Tata McGraw Hill, 10th Edition, Reprint, 2007.
3. Pang-Ning Tan, Michael Steinbach and Vipin Kumar: Introduction to Data Mining, Pearson Education, 2007.
4. G. K. Gupta: Introduction to Data Mining with Case Studies, Easter Economy Edition, Prentice Hall of India, 2006.

6. Time Series and Econometrics

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

Time Series: Time series and Forecasting, Nature and uses of forecasts, Explanatory versus time series forecasting, Time series methods: Decomposition methods, Exponential smoothing methods.

Econometrics: An introduction to econometrics, two-variable Regression Analysis, Multiple regression analysis. Multicollinearity, Heteroscedasticity, Autocorrelation and lag models.

References /Suggested Readings:

1. Damodar Gujarati: Basic Econometrics, Tata McGraw-Hill, 5th edition, 2012.
2. J. Johnston and J.E. DiNardo: Econometric Methods, 4th edition, 2007.
3. Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffrey Vining: Introduction to Linear Regression Analysis, 5th Edition, 2012.
4. Douglas C. Montgomery, Cheryl L. Jennings, Murat Kulahci: Introduction to Time Series Analysis and Forecasting, 2nd Edition. 2011.

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. CAPM and Portfolio Selection Models.

References /Suggested Readings:

1. Gary L. Lilien, Philip Kotler, K. Sridhar Moorthy: Marketing Models, Prentice Hall of India, 2003.
2. J. C. Van Horne, J. M. Wachowicz: Fundamentals of Financial management, 13th Edition, Prentice Hall of India, 2009.
3. G. Cornuejols, R. Tutuncu: Optimization Methods in Finance, Cambridge University Press, 2007.
4. Wayne L. Winston: Operations Research. Applications and Algorithms, 4th Edition, Duxbury Press, 2003
5. J.C.T Mao: Quantitative Analysis of Financial Decisions, Mac Millan, 1969.
6. P.T Fitzroy: Analytical Methods for Marketing Management, McGraw Hill, 1976.

8. Project Work / Industrial Training

Students are expected to carry out independent project in the industry on a topic assigned to him/her under the supervision of faculty member. At the completion of project students are expected to write a report and make a presentation.

Ability Enhancement Electives (skill based)

1. Data Analysis

Objective*: To enable the student to explore the real data sets with analytical tools.*

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

Data Analysis: Pictorial representation-Cross tabulation, Bar Chart, Pei Chart, Histogram, Ogive etc. Numerical calculation-Measures of Central Tendency-mean, median, mode, quartiles, deciles and percentiles. Measures of Dispersions- range, mean deviation, quartile deviation and standard deviation. Correlation, Regression.

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

Reference/Suggested Readings:

1. David Whigham: Business Data Analysis using Excel, Oxford University Press, 2007.
2. C.R. Kothari. Research methodology: methods and techniques. New Age International, 2011.
3. D. Chawla and N. Sondhi. Research Methodology: Concepts and Cases. Vikas Publishing House Pvt. Ltd, 2011.
4. R. Kumar. Research Methodology: A Step - by - Step Guide for Beginners. Sage South Asia; Third edition, 2011.

2. Numerical Methods

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

Solution of transcendental equations: Bisection Method, Newton Raphson Method ,Secant Method, Regula-falsi method.

Solution of system of linear equations: Gauss Elimination method, Gauss Jordan, Iterative methods: Gauss-Jacobi Method, Gauss-Seidel Method.

Interpolation and Numerical integration: Lagrange Interpolation, Trapezoidal Rule, Simpson's Rule.

Solution of ordinary differential equations: Euler's Method, modified Euler's Method, Runge's method, Runge-Kutta Method.

References /Suggested Readings:

1. M. K. Jain, S. R. K. Iyengar and R. K. Jain. Numerical Methods for Scientific and Engineering Computation, 4th Edition, 2004.
2. Kendall Atkinson, "An Introduction to Numerical Analysis", 2nd edition, 1989.
3. E. Joseph Billo : Excel for Scientists and Engineers: Numerical Methods, Wiley-Blackwell, 2007.

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 using spanning tree, Simulation, Knapsack problem, Set Covering Problem, Fixed Charge Transportation Problem, Project Selection Problem.

References /Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
2. Wayne L. Winston and M. Venkataramanan: Introduction to Mathematical Programming: Applications and Algorithms, 4th edition, Duxbury Press, 2002.
3. A. Ravindran, Don T. Phillips, James J. Solberg: Operations Research. Principles and Practice, John Wiley & Sons, 2005.
4. G. Hadley: Nonlinear and Dynamic Programming, Addison-Wesley, 1964.

4. Introduction to Information Technology

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

Information Technology: Understanding the Digital Domain – Representation of Numbers and text in binary codes.

Fundamentals of Computers: Computer Hardware, Computer Software, Translators, Computer language, Transmission of Information.

Fundamentals of Communications– Fiber Optics, Wireless Communication.

Computer Networking: Goals, Topologies, Local Area Networks, Wide Area Networks, Communication Protocols.

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

References /Suggested Readings:

1. Pelin Aksoy, Laura DeNardis: Introduction to Information Technology, Cengage Learning India Private Limited, First Indian Reprint 2008.
2. Peter Norton: Introduction to Computers, Tata McGraw-Hill, 6th Edition. 2006.

Generic Elective / Interdisciplinary

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.

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.

Reference/Suggested Readings:

1. G. Hadley: Linear Programming. , Reprint 2002.
2. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, John Wiley & Sons, 2005.
3. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
4. F.S. Hillier. G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill. 2010.

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

1. To solve Linear Programming Problem using Graphical Method with
   (i) multiple constraints
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
2. Solution of LPP with simplex method.
3. Solution of LPP with unrestricted variables through Simplex method.
4. Problem solving using M-Charnes method.
5. Problem solving using Two Phase method.

6. Illustration of following special cases in LPP using Simplex method
   (i) Unrestricted variables
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
7. Problems based on Dual simplex method.
8. Problems based on sensitivity analysis.

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 control (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.

Reference/Suggested Readings:

1. Donald Waters: Inventory Control and Management, John Wiley, 2010.
2. F.S. Hillier and G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill, 2010.
3. G. Hadley, T. M. Whitin: Analysis o f Inventory- Systems, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc., 1979.
4. Buffa, Elwood S. and Sarin Rakesh K.: Modern Production / Operations Management 8th Edition, Wiley India, 2009.

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 EPQ model.
4. To find optimal inventory policy for EOQ model with backorders.
5. To solve EOQ model with constraints.
6. To solve All-units quantity discounts 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 demand.

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)

Assignment problem: formulation as a linear programming problem, Hungarian method, Travelling salesman problem: Branch and Bound solution algorithm.

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

Reference/Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
2. F.S. Hillier and G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill. 2010.
3. A. Ravindran, Don T. Phillips, James J. Solberg: Operations Research. Principles and Practice, John Wiley & Sons, 2005.
4. Wayne L. Winston, Operations Research: Applications and Algorithms, 4th Edition, Duxbury Press, 2003.
5. Ferdinand K. Levy, Jerome D. Wiest: A Management Guide to PERT/CPM, 2nd Edition, Prentice Hall, 1977.

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

1. Solve Transportation Problem as a LPP.
2. Solve Assignment Problem as a LPP.
3. Solve of travelling salesman problem.
4. Solve shortest path problem as a LPP.
5. To perform Project scheduling of a given project (Deterministic case-CPM).
6. To perform Project scheduling of a given project (Probabilistic case-PERT).
7. To perform Crashing of a given Project.

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.

Reference/Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, 2010.
2. P. R. Thie, G. E. Keough: An Introduction to Linear Programming and Game Theory, Wiley, New Jersey, 3rd edition, 2008.
3. F.S. Hillier and G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill, 2010.

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

1. Solution of IPP using Branch and Bound method.
2. Solution of IPP using Gomory's cutting plane method.
3. Solution of Capital Budgeting Problem.
4. Solution of Fixed charge problem.
5. Solution of cargo loading problem.
6. Solution of production planning problem.
7. Solution of Two-Person Zero-Sum pure and mixed strategy game.
8. Linear programming solution of game problem.

5. Queuing and Reliability Theory

Objective: The aim of the paper is to introduce the basics of queuing and reliability theory.

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.

Reference/Suggested Readings:

1. F.S. Hiller and G.J. Lieberman: Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata McGraw Hill, 2010.
2. D. Gross, John F. Shortle, James M. Thompson and C. Harris, Fundamentals of Queuing Theory, 4th Edition, Wiley India, 2008.
3. Srinath. L. S., Reliability Engineering, East West Press, New Delhi, 2005.
4. Trivedi K.S., Probability and Statistics with reliability, Queuing and Computer Science Applications, Prentice-Hall of India, New Delhi, 2011.

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

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. Problems based on Simulation: Random number generation. Problems based on Monte Carlo method.
6. Calculation of hazard rate, MTBF for series & parallel system
7. Calculation of hazard rate, MTBF for Mixed configuration.
8. Problems based on reliability optimization.

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.

Reference/Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, -2010.
2. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Application, Narosa Publishing House, 2009.
3. A. Ravindran, D. T. Phillips and James J. Solberg: Operations Research- Principles and Practice, Wiley India Edition, 2009.
4. S.M. Sinha : Mathematical Programming-Theory and Methods, Elsevier Science, 1st Edition, 2006.
5. F.S. Hillier and G.J. Lieberman : Introduction to Operations Research- Concepts and Cases, 9th Edition, Tata Mc Graw Hill, 2010.

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

1. To determine local/Relative optima of a given unconstraint problem.
2. Test whether the given function is concave/convex.
3. Test whether the given matrix is positive definite/negative definite/semi positive definite/ semi negative definite
4. Solution of optimization problems using Karush-Kuhn-Tucker conditions.
5. Solution of Quadratic programming problem by Wolfe's method.
6. Dynamic programming applications for optimization problems:
7. Additive separable returns for objectives with additive constraints.
8. Additive separable returns for objectives with multiple constraints.
9. Multiplicative separable returns for objectives with additive constraints.
10. Graphical solution of weighted Goal programming.
11. Graphical solution of pre-emptive Goal programming.