Choice Based Credit System (CBCS)

UNIVERSITY OF DELHI

DEPARTMENT OF OPERATIONAL RESEARCH

UNDERGRADUATE PROGRAMME
(Courses effective from Academic Year 2015-16)

SYLLABUS OF COURSES TO BE OFFERED
Core Courses, Elective Courses & Ability Enhancement Courses

Disclaimer: The CBCS syllabus is uploaded as given by the Faculty concerned to the Academic Council. The same has been approved as it is by the Academic Council on 13.7.2015 and Executive Council on 14.7.2015. Any query may kindly be addressed to the concerned Faculty.

Undergraduate Programme Secretariat

Preamble

The University Grants Commission (UGC) has initiated several measures to bring equity, efficiency and excellence in the Higher Education System of country. The important measures taken to enhance academic standards and quality in higher education include innovation and improvements in curriculum, teaching-learning process, examination and evaluation systems, besides governance and other matters.

The UGC has formulated various regulations and guidelines from time to time to improve the higher education system and maintain minimum standards and quality across the Higher Educational Institutions (HEIs) in India. The academic reforms recommended by the UGC in the recent past have led to overall improvement in the higher education system. However, due to lot of diversity in the system of higher education, there are multiple approaches followed by universities towards examination, evaluation and grading system. While the HEIs must have the flexibility and freedom in designing the examination and evaluation methods that best fits the curriculum, syllabi and teaching–learning methods, there is a need to devise a sensible system for awarding the grades based on the performance of students. Presently the performance of the students is reported using the conventional system of marks secured in the examinations or grades or both. The conversion from marks to letter grades and the letter grades used vary widely across the HEIs in the country. This creates difficulty for the academia and the employers to understand and infer the performance of the students graduating from different universities and colleges based on grades.

The grading system is considered to be better than the conventional marks system and hence it has been followed in the top institutions in India and abroad. So it is desirable to introduce uniform grading system. This will facilitate student mobility across institutions within and across countries and also enable potential employers to assess the performance of students. To bring in the desired uniformity, in grading system and method for computing the cumulative grade point average (CGPA) based on the performance of students in the examinations, the UGC has formulated these guidelines.

CHOICE BASED CREDIT SYSTEM (CBCS):

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Therefore, it is necessary to introduce uniform grading system in the entire higher education in India. This will benefit the students to move across institutions within India to begin with and across countries. The uniform grading system will also enable potential employers in assessing the performance of the candidates. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations, the UGC has formulated the guidelines to be followed.

Outline of Choice Based Credit System:

1. **Core Course:** A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.
2. **Elective Course:** Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.
   - **2.1 Discipline Specific Elective (DSE) Course**: Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).
   - **2.2 Dissertation/Project**: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.
   - **2.3 Generic Elective (GE) Course**: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective.
     P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.
3. **Ability Enhancement Courses (AEC)/Competency Improvement Courses/Skill Development Courses/Foundation Course:** The Ability Enhancement (AE) Courses may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC). "AECC" courses are the courses based upon the content that leads to Knowledge enhancement. They ((i) Environmental Science, (ii) English/MIL Communication) are mandatory for all disciplines. AEEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.
   - **3.1** AE Compulsory Course (AECC): Environmental Science, English Communication/MIL Communication.
   - **3.2** AE Elective Course (AEEC): These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction.

Project work/Dissertation is considered as a special course involving application of knowledge in solving / analyzing /exploring a real life situation / difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.

Details of Courses Under Undergraduate Programme (B.A./ B.Com.)

Course	***Credits**	
	Paper+ Practical	Paper + Tutorial
I. Core Course	12X4= 48	12X5=60
(12 Papers)		
Two papers – English		
Two papers – MIL		
Four papers – Discipline 1.		
Four papers – Discipline 2.		
Core Course Practical / Tutorial*	12X2=24	12X1=12
(12 Practicals)		
II. Elective Course	6x4=24	6X5=30
(6 Papers)		
Two papers- Discipline 1 specific		
Two papers- Discipline 2 specific		
Two papers- Inter disciplinary		
Two papers from each discipline of choice and two papers of interdisciplinary nature.		
Elective Course Practical / Tutorials*	6 X 2=12	6X1=6
(6 Practical/ Tutorials*)		
Two papers- Discipline 1 specific		
Two papers- Discipline 2 specific		
Two papers- Generic (Inter disciplinary)		
Two papers from each discipline of choice including papers of interdisciplinary nature.		
III. Ability Enhancement Courses		
1**. Ability Enhancement Compulsory**	2 X 2=4	2 X 2=4
(2 Papers of 2 credits each)		
Environmental Science		
English Communication/MIL		
2**. Ability Enhancement Elective**	4 X 2=8	4 X 2=8
(Skill Based)		
(4 Papers of 2 credits each)		
	Total credit= 120	**Total = 120**

- **Optional Dissertation or project work in place of one elective paper (6 credits) in 6th Semester**

Institute should evolve a system/policy about ECA/ General Interest/Hobby/Sports/NCC/NSS/related courses on its own.

***wherever there is a practical there will be no tutorial and vice-versa.**

Scheme for Choice Based Credit System in

B.A. (Program) Operational Research

Sem.	CORE COURSE (DCC) (12)	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Course (SEC) (4)	Discipline Specific Elective DSE
I	Introduction to Operational Research and Linear Programming (Theory+ Practical)	**AECC 1** (English/MIL Communication) /Environmental Science		
II	Inventory and Marketing Management (Theory+ Practical)	**AECC 2** Environmental Science/ (English/MIL Communication)		
III	Optimization Techniques(Theory+ Practical)		**SEC - OR 1** Operational Research Applications	
IV	Network Models and Scheduling Techniques(Theory+ Practical)		**SEC - OR 2** Project Management	
V			**SEC - OR 3** Portfolio Optimization	**DSE 1** 1) Queueing and Reliability Theory (Theory and practical) **OR** **2)** Quality Management (Theory and Tutorials)
VI			**SEC - OR 4** Business Data Analysis	**DSE 2** 1) Integer Programming and Theory of Games (Theory and practical) **OR** 2) Logistics and Supply Chain Management (Theory and Tutorials)

Discipline Core Course (DCC) (Credit: 6 each)

Core Course 1- Operational Research

DCC 1A Introduction to Operational Research and Linear Programming (Theory and practical)
DCC 1B Inventory and Marketing Management (Theory and practical)
DCC 1C Optimization Techniques (Theory and practical)
DCC 1D Network Models and Scheduling Techniques (Theory and practical)

Discipline Specific Electives (DSE) (Credit: 06 each)

DSE 1 (choose one)

1. Queueing and Reliability Theory (Theory and practical)
2. Quality Management (Theory and Tutorials)

DSE 2 (choose one)

1. Integer Programming and Theory of Games (Theory and practical)
2. Logistics and Supply Chain Management (Theory and Tutorials)

Skill Enhancement Course (SEC) (Credit: 02 each)

SEC - OR 1

1. Operational Research Applications

SEC - OR 2

1. Project Management

SEC - OR 3

1. Portfolio Optimization

SEC - OR 4

1. Business Data Analysis

Details of Courses under B.A. (Program)

Course		*Credits
	Theory + Practical	Theory + Tutorials
I. Core Course (12 Papers) 04 Courses from each of the 03 disciplines of choice	12×4 = 48	12×5 = 60
Core Course Practical / Tutorial* (12 Practical/ Tutorials*) 04 Courses from each of the 03 Disciplines of choice	12×2 = 24	12×1 = 12
		Total Credits for DCC=72
II. Elective Course (6 Papers) Two papers from each discipline of choice including paper of interdisciplinary nature.	6×4 = 24	6×5 = 30
Elective Course Practical / Tutorials* **(6 Practical / Tutorials*)** Two Papers from each discipline of choice including paper of interdisciplinary nature	6×2 = 12	6×1 = 6
		Total Credits for DSE =36

• Optional Dissertation or project work in place of one Discipline elective paper (6 credits) in 6th Semester

III. Ability Enhancement Courses		
1.**Ability Enhancement Compulsory** (2 Papers of 2 credits each) **Environmental Science** **English/MIL Communication**	2×2 = 4	2×2 = 4
2. **Skill Enhancement Course (Skill Based) (4 Papers of 2 credits each)**	4×2 = 8	4×2 = 8
	Total credit = 120	**Total credit = 120**

Institute should evolve a system/policy about ECA/ General Interest/ Hobby/ Sports/ NCC/ NSS/ related courses on its own.

***wherever there is practical there will be no tutorials and vice-versa**

DCC 1A: Introduction to Operational Research and Linear programming

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 (LPP), 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.

References /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.

DCC 1B: Inventory Systems and Marketing Management

Concepts and problems in Inventory Systems, classification of Inventory Systems, different costs in Inventory Systems and method of their estimation. Deterministic Inventory models with and without lead time and with and without shortages. Inventory models with All Units Quantity Discounts. Single period stochastic inventory models. Production scheduling problems.

Concept of marketing and its role in organization. Marketing decisions, scientific marketing analysis. Uses and limitations of mathematical models in marketing , classification of market structure in competitive conditions. Demand elasticity, joint optimization of price, quality and promotional efforts. Pricing decisions, media allocation for advertisement. Brand switching analysis.

References /Suggested Readings:

1. Donald Waters: Inventory Control and Management, John Wiley, 2010.
2. Buffa, Elwood S. and Sarin Rakesh K.: Modern Production/Operations Management, 8th Edition, Wiley India, 2009.
3. Zipkin, Foundations of Inventory Management, McGraw Hall Inc., 2000.
4. Philip Kotler, Marketing Management, 13th Ed., Prentice Hall of India, 2008.
5. Graham J. Hooley and Michael K. Hassey, Quantitative Methods in Marketing, 2nd Ed., International Thomson Business Press, 1999.

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.
8. Problems based on media allocation for advertisement.
9. Problems based on Brand switching analysis.

DCC 1C: Optimization Techniques

Non-Linear Programming (NLP): Convex function and its properties, basics of NLP, Method of Lagrange multiplier, Karush-Kuhn-Tucker optimality conditions, Quadratic Programming: 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. Graphical solution.

References /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.

DCC 1D: Network Models and Scheduling Techniques

Transportation problem: formulation as a linear programming problem, methods to find initial basic feasible solution (NWCM, LCM, VAM) and optimal solution (MODI), degeneracy, unbalanced transportation problem, prohibited transportation problem, maximization type transportation problem, transhipment problem.

Assignment problem: formulation as a linear programming problem, Hungarian method, degeneracy, unbalanced assignment problem, prohibited assignment problem, maximization type assignment problem, 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.

Network optimization models: Basic concepts, Shortest path problem, Minimum spanning tree problem.

References /Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, - 2010.
2. Frederick Hillier and Gerald Lieberman, Introduction to Operations Research. 9th Edition, McGraw-Hill Professional, 2010.
3. 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. Solution of Transportation Problem as a LPP.
2. Solution of Assignment Problem as a LPP.
3. Solution of travelling salesman problem.
4. Solution of Shortest path problem as a LPP.
5. Project planning (Deterministic case-CPM).
6. Project planning (Probabilistic case-PERT).
7. Crashing of the Project.
8. Solution of shortest path problem.
9. Solution of minimum spanning tree problem.

DSE 1.1: Queuing and Reliability Theory

General concepts of queueing system and Introduction to stochastic processes, Measures of performance, Arrival and Service processes, Kendall's notation, Single server and multi server models, channels in parallel with limited and unlimited queues –M/M/1/K, M/M/C. Queues with unlimited service, Finite source queues, Applications of Simple Queuing Decision Models, Design and Control Models.

Basics of reliability, classes of life distributions, Reliability function, Mean time before failure (MTBF)and Hazard rate of Exponential and Weibull distributions, Reliability of configurations-series, parallel, mixed configuration, k out of n system and standby system, Reliability models, Concepts and definitions of Preventive Maintenance, Corrective Maintenance and Age Replacement.

References /Suggested Readings:

1. D. Gross, C. M. Harris, Fundamentals of Queueing Theory, 3rd Ed., John Wiley and Sons Inc., 2002.
2. U N Bhatt: An Introduction to Queueing Theory: Modeling and Analysis in Applications (Statistics for Industry and Technology), Birkhauser Boston, 2008.
3. John G. Rau, Optimization and Probability in Systems Engineering, V. N. Reinhold Co. 1970.
4. Marvin Rausand and Arnljot Hoyland, System Reliability Theory: Models, Statistical Methods and Applications, 2nd Ed. John Wiley and Sons Inc. 2003

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

DSE 1.2: Quality Management

Overview of quality, History of Quality, Competitive Advantage, Industrial Perspective, Taguchi Loss function concept.

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.

Process capability meaning –significance and measurement, Six Sigma- features, goals and implementation, DMAIC and DMADV.

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

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.

DSE 2.1: Integer Programming and Theory of Games

Integer Programming Problem (IPP): Pure and Mixed IPP, Methods for solving IPP: Branch and Bound Method, Gomory's Cutting Plane Method, Applications of IPP, 0-1 Programming: applications, enumeration algorithm.

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

References /Suggested Readings:

1. Hamdy A. Taha: Operations Research-An Introduction, Prentice Hall, 9th Edition, - 2010.
2. Frederick Hillier and Gerald Lieberman, Introduction to Operations Research. 9th Edition, McGraw-Hill Professional, 2010.
3. P. R. Thei, G. E. Keough: An introduction to Linear Programming and Game Theory. Wiley, New Jersey, 3rd Ed., 2008.
4. S. Chandra, Jayadeva, Aparna Mehra: Numerical Optimization with Application, Narosa Publishing House, 2009.

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.

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DSE 2.2: Logistics and Supply Chain Management

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.

SEC – OR 1: Operational Research Applications

Media allocation problem, Cargo Loading Problem, Production Scheduling Problem, Cutting stock 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. A. Ravindran, Don T. Phillips, James J. Solberg: Operations Research. Principles and Practice, John Wiley & Sons, 2005.
3. Frederick Hillier and Gerald Lieberman, Introduction to Operations Research. 9th Edition, McGraw-Hill Professional, 2010.
4. Wayne L. Winston, Operations Research: Applications and Algorithms, 4th Edition, Duxbury Press, 2003.

SEC - OR 2: Project Management

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. Goodpasture, J. C.: Quantitative Methods in Project Management, J Ross Publishing, Boca Raton, Florida, USA, 2003.
4. Meredith, J. R. and Mantel Jr., S. J.: Project Management: A Managerial Approach, John Wiley, New York. 2004.

SEC - OR 3: Portfolio Optimization

Financial markets. Investment objectives. Measures of return and risk. Types of risks. Portfolio of assets. Expected risk and return of portfolio. Diversification. Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolio performance evaluation measures.

References /Suggested Readings:

1. F.K. Reilly, Keith C. Brown, *Investment Analysis and Portfolio Management*, 10th Ed., South-Western Publishers, 2011.
2. H.M. Markowitz, *Mean-Variance Analysis in Portfolio Choice and Capital Markets*, Blackwell, New York, 1987.
3. D.G. Luenberger, *Investment Science*, 2nd Ed., Oxford University Press, 2013.

SEC - OR 4: Business Data Analysis

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. 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 Edition, Tenth 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