PROSPECTUS
B.Tech in
Industrial Engineering and Operations Research

Indian Institute of Technology Bombay
2024

1. About Department

Department of Industrial Engineering and Operations Research (IEOR) at IIT Bombay has become one of the well-recognized places in India for the fields of Operations Research, Industrial Engineering, Service Systems Engineering, Management Science, and related areas. IEOR has seen steady growth in both numbers and quality over the last two decades and has been adapting itself to the changes in the field. In particular, the last five years (2018-22) have seen IEOR strengthening its core and expanding in new dimensions. It has grown from a core of computational and scientific approaches to planning problems. Application of a range of mathematical and computational techniques to various issues in resource allocation and the analysis of complex physical and business systems is the broad theme of academic activities in IEOR.

The department has been offering graduate programs of Ph.D., M.Tech, and M.Sc for many decades, and will now be starting the B.Tech program in 2024. The department has been offered a range of courses on both the basics and advanced topics in operations research and industrial engineering. The courses are also popularly taken as electives by UG students of other programs. IEOR courses regularly see a total enrollment of 1000+ students per semester, across all our courses.

Faculty and students pursue diverse research directions, encompassing both methodological and applied areas. IEOR possesses particular strength in optimization techniques, machine learning, stochastic models, and game theory. Notably, research in machine learning has seen significant growth in the past six years. This growing strength in various domains is reflected by research contributions such as published books and articles in high-quality journals and conferences. The department also excels in applying these methodologies to practical problems in logistics, supply chains, sustainability, healthcare, and security. This advancement is driven by the increasing number of PhD students, postdoctoral researchers, research scientists, and research assistants joining our program.

2. Undergraduate Program (B.Tech in IEOR)

2.1 Introduction

The undergraduate program, B.Tech. in Industrial Engineering and Operations Research at IIT Bombay aims to train students in quantitative, analytical and computational approaches to model and analyze a range of decision problems in integrated systems of people, information, technology, material, energy, environment and/or financial resources. The curriculum for UG program is for 254 credits, consisting of department core courses, department core labs, and other courses. The students can also get Honors a in IEOR by completing additional credit requirements. This document gives the prospectus for the UG program along with the complete details of the proposed coursework.

2.2 Why B.Tech in IEOR?

The theme of IEOR is design of efficient operating policies for systems and optimal allocation of resources. These days technology enables capture of various types of data, including the transactional type. Design of relevant decision making algorithms for operational excellence is seen as a realistic goal and is sought by competitive and forward looking firms from both public and private sectors. Industries (product and services), technology innovation centers, research labs and academia are in need of quality manpower trained not only in modelling, analytical and computational skills, but also with scalable and transferable skill sets to apply in a range of business and industry settings. A graduate of IEOR can contribute to various sectors, including but not limited to, manufacturing, logistics & transportation, business analytics, e-commerce/ e-tailers, online marketplaces, production, agriculture, financial services, healthcare, security, information & telecommunication, and other services.

World Economic Forum in their 2020 report[1], presents two interesting charts, which are reproduced below. THe figure on the left shows the job skills with increasing demand trend, and the figure on the right shows the top skills for 2025. The BTech IEOR curriculum has been designed appropriately to help contribute significantly to meet the demands and well as provide leadership.

[1] Future of Jobs Report 2020 https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf

↗ Increasing demand

1	Data Analysts and Scientists
2	AI and Machine Learning Specialists
3	Big Data Specialists
4	Digital Marketing and Strategy Specialists
5	Process Automation Specialists
6	Business Development Professionals
7	Digital Transformation Specialists
8	Information Security Analysts
9	Software and Applications Developers
10	Internet of Things Specialists
11	Project Managers
12	Business Services and Administration Managers
13	Database and Network Professionals
14	Robotics Engineers
15	Strategic Advisors
16	Management and Organization Analysts
17	FinTech Engineers
18	Mechanics and Machinery Repairers
19	Organizational Development Specialists
20	Risk Management Specialists

- Analytical thinking and innovation
- Active learning and learning strategies
- Complex problem-solving
- Critical thinking and analysis
- Creativity, originality and initiative
- Leadership and social influence
- Technology use, monitoring and control
- Technology design and programming
- Resilience, stress tolerance and flexibility
- Reasoning, problem-solving and ideation

Source: Future of Jobs Report 2020, World Economic Forum.

2.3 Admission and Intake

Admission to B.Tech IEOR will be through JEE Advanced. Student intake is approx 35 students per batch.

2.4 Curriculum of B.Tech Program

The semester-wise program structure is given below. The courses with the tag *IE* are the IEOR courses for the UG program. The courses will have a mix of classroom instruction, practical work, exposure to industry and other sectors, project work, and independent work by students. Teaching assistants and other resource persons will support course instruction. The program will be evaluated through regular exams, assignments, project work presentations, and group work.

L = Lectures, T = Tutorials, P = Practical, C = Credits
Numbers refer to hours per week (contact hours per week for L, T, and P and Total = cumulative hours expected to be spent on the course per week).

SEMESTER I						SEMESTER II					
		L	T	P	C			L	T	P	C
IE101	Introduction to IE and OR (DIC-1)	3	0	0	6	IE102	Probability and Statistics	3	0	0	6
MA105	Calculus	3	1	0	8	MA110	Linear Algebra & Differential Equations	3	1	0	8
CS101	Computer Programming & Utilization	2	0	2	6	BB101	Biology				6
MS101	Makerspace				8		Intro to HASMED (2 half)				8
CH117	Chemistry Lab				3	PH117	Physics Lab	0	0	3	3
	NCC/NSS/NSO						NCC/ NSS/ NSO				
	Gender Sensitisation										
	TOTAL				31		TOTAL				31

SEMESTER III						SEMESTER IV					
		L	T	P	C			L	T	P	C
EC101	Economics	3	0	0	6		Design Thinking -				6
IE209	Linear Optimization and Network Flows	3	0	0	6	IE208	Nonlinear and Discrete Optimization	3	0	0	6
IE207	Industrial Systems	3	0	0	6	IE210	Optimization Modeling Lab	0	0	3	3
IE205	Industrial Engineering Lab	0	0	3	3	IE206	Introduction to AI/ML	3	0	0	6
IE203	Data Structures and Algorithms	3	0	0	6	IE201	Data Analytics, AI/ML Lab	0	0	3	3
IE211	Programming & Computing Lab	0	0	3	3	IE204	Feedbacks and Dynamics	3	0	0	6
ES/HS 250	Environmental Studies	3	0	0	6	IE202	Digital Enterprise Systems Lab	0	0	3	3
	TOTAL				36		TOTAL				33

SEMESTER V						SEMESTER VI					
		L	T	P	C			L	T	P	C
IE301	Operations Analysis	3	0	0	6	IE302	Logistics and Supply Chains	3	0	0	6
IE303	Simulation	3	0	0	6	IE304	Risk and Uncertainty	3	0	0	6
IE307	Stochastic Processes & Queueing Systems	3	0	0	6		Department Elective 1				6
IE305	Simulation Lab	0	0	3	3		STEM Elective 1				6
	HASMED Elective 1				6		HASMED Elective 2				6
	Flexible Elective 1				6						
	TOTAL				33		TOTAL				30
	(Honors Elective 1)				*6*		*Honors Elective 2*				*6*
SEMESTER VII						SEMESTER VIII					
		L	T	P	C			L	T	P	C
	BTP1/ Dept Elective				6		BTP2 or Dept Elec (2 courses)				12
	Department Elective 2				6		Department Elective 3				6
	Flexible Elective 2				6		Flexible Elective 4				6
	Flexible Elective 3				6		Flexible Elective 5				6
	STEM Elective 2				6						
	TOTAL				30		TOTAL				30
	Honors Elective 3				*6*		*Honors Elective 4*				*6*

Department Electives include all the currently available IE courses, the list of which is available in IEOR website.

2.5 B.Tech Honors option

Students need to complete additional 4 courses (24 credits) to get Honors.

BTP1 (6 credits) and BTP2 (12 credits) are mandatory for getting BTech (Honors) in IEOR. BTP-1 registration will be based on instructor consent. BTP-2 registration will be subject to satisfactory performance in BTP-1 (grade of BB or higher in BTP-1) and instructor consent.

2.6 Detailed course syllabus

IE101 : Introduction to IE and OR

Credits	L: 3 T: 0 P:0 C:6
Prerequisites	None
Course topics/ subtopics	The course briefly introduces the evolution of various aspects of IE and OR over the past decades, and its current and future prospects. The different broad theme areas relevant to IEOR may also be discussed. Students will be encouraged towards problem scoping and thinking from first principles on a range of issues. Examples of modern work systems designed to provide value in manufacturing and services (large factory, bus terminus, hospital, primary school, sports facility for training and events) will be discussed. Applications to a wide range of sectors including manufacturing, health care, sports, logistics, academics, banks, etc. will be discussed. Links to sustainability and Sustainable Development Goals will be discussed to make students aware of challenges and opportunities.
References	Bonnie Boardman, Introduction to Industrial Engineering, 2020. Available in OpenTextBook Library https://open.umn.edu/opentextbooks/textbooks/892 Richard C. Larson and Amedeo R. Odoni, URBAN OPERATIONS RESEARCH, MIT Press Goldratt, 2004, Goal: A Process of Ongoing Improvement, 3rd edition, Routledge P. Senge, Fifth Discipline, 2006 Dimitris Bertsimas and Robert Freund, Data, Models and Decisions, Dynamic Ideas LLC, 2004

IE102 : Probability and Statistics

Credits	L: 3 T: 0 P:0 C:6
Prerequisites	None
Course topics/ subtopics	The course covers the basics on probability and statistics. Topics include: ● Descriptive Statistics & Data Handling, ● Probability: Sample spaces & events, conditional probability, Notions of independent events, Bayes Theorem, Discrete and Continuous random variables; probability mass functions, density functions, distributions, Expectations & Variance & their properties, covariance, correlation ● Conditional random variables, conditional expectations, joint and marginal distributions, laws of large numbers, Central Limit Theorem ● Some of the useful & common Distributions such as Bernoulli, Binomial, Poisson, Exponential, Uniform, Normal ● Statistical inference basics, including parameter estimation, hypothesis testing (t-test, chi-square tests) ● Introduction to time series data ● Examples and use of spreadsheets / software for computations ● Applications to business decisions
References	● Sheldon Ross, Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition, Academic Press, 2014. ● Maurice DeGroot and Mark Schiverser, Probability and Statistics, 4th edition, Pearson, 2011 ● Dennis Wackerly, William Mendenhall, and Richard L. Scheaffer (2007) Mathematical Statistics with Applications, 7th edition, Duxbury Resource Center.

IE209 : Linear Optimization and Network Flows

Credits	L: 3 T: 0 P:0 C:6
Prerequisites	None
Course topics/ subtopics	1. **Formulating Linear Optimization Models.** Examples from production planning, scheduling, investment analysis, blending products, ridesharing, sports, healthcare, etc. Modeling problems with piecewise linear convex functions. **2. Solving Linear Optimization Problems.** Extreme point optimality. Basic feasible solutions and the standard-form LP. The simplex method. **3. Linear Optimization Software.** Solving linear programming problems using software tools like PuLP. Extracting useful information from the solutions. **4. Linear Optimization Duality.** How to get bounds on the objective function? The dual Linear Program. Relationship between primal and dual linear programs. Complementary slackness and sensitivity analysis. **5. Network Flow Problems.** Linear Programming formulations of Shortest Path, Maximum Flow, Min Cost flow, and their duals. Emphasize that most shortest path algorithms solve the dual LP. Modeling problems as shortest path problems—production planning, cyclic scheduling, etc. Maximum Flow and minimum cuts. Modeling problems such as Assignment, Baseball Elimination, Open pit mining, etc. **6. Algorithms for Network Flow Problems.** A brief introduction to algorithms for shortest path problems. Dijkstra's Algorithm. Practical algorithms like the A* algorithm.
References	Wayne Winston, ***Operations Research: Applications and Algorithms***, 2003. Jon Lee, **A First Course in Linear Optimization**, Second Edition, Reex Press, 2013. Bradley, Hax, and Magnanti, **Applied Mathematical Programming,** 1977 Ahuja, Magnanti, and James B. Orlin, **Network Flows: Theory, Algorithms, and Applications,** 1993

IE207 : Industrial Systems

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	None
Lab topics/ sessions	This course gives an introduction to the world of manufacturing and other work systems, associated terminologies and activities, various basic models and methods to help understand basic factory operations, and in performance assessment. ● Principles of Management, Scientific Management, Concepts Introduction: Process of Manufacturing, Typical Performance measures, Terminologies, Basic budgeting principles, including breakeven analysis. ● Introduction to various Manufacturing technologies, Operations Process Charts and Process Planning, Work methods analysis, Work measurement & improvement, Gantt Charts, ● Basic Factory Dynamics, Little's Law, Influence of Variability on factory dynamics, Line Balancing ● Concepts of Value Stream Mapping, Lean, JIT ● Flow shops and job shops, Scheduling, Basic material management, Warehousing, Storage & Retrieval, Material handling systems ● Introduction to Service operations and related decision models ● Location considerations of facilities (cost, accessibility to users and also to physical resources needed for the facility) ● Layout and relative location of departments, equipment and human work spaces for the facility to operate effectively.
References	● Spearman and Hopp, 2011, Factory Physics, 3rd ed., Waveland Press ● Nahmias and Olsen, 2015, Production and Operations Management, 7th edition, Waveland Press ● Aksin, 1993, Modeling and Analysis of Manufacturing Systems, 1st ed, John Wiley & Sons ● Robert, J, Graham, C and M Shulver, 2017, Service Operations Management:Improving Service Delivery, 4th ed Pearson

IE205 : Industrial Engineering Lab

Credits	L:0 T: 0 P: 3 C: 3
Prerequisites topics	None
Lab topics/ sessions	This course gives an introduction to the world of manufacturing and other work systems Lab sessions will allow students to explore ● Various Manufacturing technologies, Making products individually vs. assembly line; Manufacturing Flows, Blocking & Bottleneck; ● Activity charts and visualizing and quantifying flows of people, material and information; Value Stream Mapping, in industrial and service systems ● Understanding processes and measurements using Time & Motion Study; ● Understand Material Handling Systems, Facility Layouts, Warehousing; Designing queues ● Factory /Warehouse/ eRetailers Visits may also be included
References	● Spearman and Hopp, 2011, Factory Physics, 3rd ed., Waveland Press ● Goldratt, 2004, Goal: A Process of Ongoing Improvement, 3rd edition, Routledge ● Niebel, W. B. and Freivalds, A, 2004, Methods, standards, and work design, McGraw Hill. ● Introduction to Work Study, International Labor Organization, Third Revised Edition.

IE203 : Data Structures and Algorithms

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites	None
Lab topics/ sessions	1. Object oriented programming: Concepts and use in data structures. 2. Complexity analysis: Computational complexity, asymptotic complexity, Big-O Notation, Omega and Theta Notations, Amortized complexity, Theory of P and NP complexity classes 3. Algorithm paradigms: greedy, divide-and-conquer, dynamic programming 3. Linked list, stacks, queues, priority queues, dequeues. 4. Recursion and Backtracking. Binary trees: creation, insertion, deletion, search, traversal. Balancing trees, self-adjusting trees. Heaps: Creation, insertion, deletion, search, traversal. 5. K-d trees, Multi-way trees: B-tree, Tries. 6. Sorting algorithms 7. Hashing algorithms. Dictionaries, skip lists. 8. Graphs: Graph representation, traversal, cycle detection, spanning trees, topological sort, Shortest path: Dijkstra's algorithm, 9. Networks: Matching, Maximum flow algorithm, Minimum cost algorithm.
References	● G. L. Heileman (2002) Data Structures Algorithms and Object Oriented Programming, Tata Mcgraw Hill. ● Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein (2003) Introduction to Algorithms and Java, 2nd edition, McGraw-Hill. ● Dasgupta, Papadimitriou and Vazirani, (2006) Algorithms, McGraw Hill ● Ellis Horowitz and Sartaj Sahni, Foundations of Computer Algorithms. ● Alfred V. Aho, John E. Hopcroft and Jeffrey Ullman (1983) Data Structures and Algorithms, Pearson Education India.

IE211 : Programming and Computing Lab

Credits	L:0 T: 0 P: 3 C: 3
Prerequisites	None
Lab topics/ sessions	Introduction to problem solving with computers using a modern language such as Python, R, SPSS, SciLab, or Julia, etc. Labs will cover Implementation of algorithms in various settings: searching, sorting, matching, numerical computing, modeling graphs and networks. Implementing iterative and recursive algorithms. Calling other programs through libraries and system calls, Testing and debugging programs; Measuring performance of programs, Notions of algorithmic complexity.
References	● John Zelle (2016) Python Programming an Introduction to computer science, 3rd edition, Franklin, Beedle Publishers ● John V. Guttag (2016) Introduction to Computation and Programming Using Python – with Application to Understanding Data, 2nd edition, The MIT Press ● Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein (2003) Introduction to Algorithms and Java, 2nd edition, McGraw-Hill. ● Other online resources such as https://www.learnpython.org/

IE208 : Nonlinear and Discrete Optimization

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	Linear and Network Optimization
Course topics/ subtopics	1. **Formulating Nonlinear Optimization Problems.** Examples from Warehouse location, EOQ, Least Squares, Markowitz Model, Matrix Completion, etc. Linear Program as unconstrained nonlinear programs. 2. **Optimality Conditions.** First and Second order optimality conditions for constrained and unconstrained problems. Necessity vs Sufficiency. 3. **Gradient Descent and Newton's Method.** Basic introduction to these algorithms and illustration of some properties on examples. Discuss convergence without proofs. 4. **Convex Optimization Problems.** How are convex optimization problems different from nonconvex optimization problems? Lagrangian duality. 5. **Formulating Discrete Optimization Problems.** Knapsack problems, Facility Location, Traveling Salesman Problem, timetabling, scheduling, etc. Modeling boolean statements, nonconvex piecewise linear objective functions. Heuristics, especially for discrete problems. Local improvement procedures such as 2-opt, and other methods. 6. **Branch-and-Bound Algorithms** Linear programming based branch and bound for integer programming problems.
References	• Nash, Sofer and Griva, Linear and Nonlinear Optimization, 2017 • Nocedal and Wright, Numerical Optimization, second edition, 2009 • Wolsey, Integer Programming, 1998 • Hillier and Lieberman, Introduction to Operations Research, 11th edition, 2021

IE210 : Optimization Modeling LAB

Credits	L:0 T: 0 P: 3 C: 3
Prerequisites topics	Should be concurrent or after at least one optimization course. Ideally concurrent or after the second optimization course.
Lab topics/ sessions	· Programming in AMPL/Julia/Python to computationally model optimization problems. · Identification of metrics of performance, certificates of infeasibility/optimality through the solver logs using various solvers (such as CPLEX, GUROBI, PuLP, MINOTAUR, Mosek, etc). · Comparison of different formulations and contrasting their computational performance viz à viz facility location, Traveling Salesman Problem, Scheduling etc. Identifying why certain formulations are better computationally. · Implementation of fundamental branching rules, cutting planes in branch and cut procedures for discrete optimization algorithms. · Introduction to Polymake/PORTA to get some hands-on perspective on polyhedral geometry. - Use of Meta-heuristics for solving optimisation models - Goal programming, Pareto optimality, Multi-objective optimisation
References	● Bynum, Hackebeil, Hart, et al, Pyomo - Optimization Modeling in Python, 2021 ● Fourer, Gay and Kernighan, AMPL: A Modeling Language for Mathematical Programming, second edition, ● Julia Programming for Operations Research 2/e, Changhyun Kwon, https://juliabook.chkwon.net/book
Remarks	The primary evaluation methodology is going to be projects, students will be learning these tools while also implementing the same as part of their projects as well.

IE206 : Introduction to Artificial Intelligence and Machine Learning

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	Probability, statistics, linear algebra

Course topics/ subtopics	• Artificial agents - nature and structure
	• Search based problem-solving
	  ○ Uninformed search and heuristic search
	  ○ Local search
	  ○ Adversarial search and constraint satisfaction
	• Propositional logic, first order logic and knowledge representation using semantic nets, taxonomy trees
	• Uncertain knowledge representation: Bayesian nets, causal nets, inference, temporal models like HMM, dynamic Bayesian nets
	• Planning: Heuristics, Hierarchical planning, planning in uncertain domains, scheduling
	• Decision networks, sequential decision making, multi-agent decision making
	• Learning from examples: regression and classification
	• Deep learning models for computer vision and NLP
	• Basics of Reinforcement learning
	• Robotics - perception, planning and control, uncertain movements
	• Humans and AI - impact, ethics, limits, laws

References	1. Stuart Russell and Peter Norvig. Artificial Intelligence: A Modern Approach. Pearson, Fourth Edition, 2020. 2. Richard E. Neapolitan and Xia Jiang. Artificial Intelligence with an Introduction to Machine Learning, CRC Press, Second Edition, 2018. 3. Tom Mitchell. Machine Learning, McGraw Hill Education, First edition, 2017. 4. Richard Duda, Peter Hart and David Stork. Pattern Classification, Wiley Interscience, Second Edition, 2007.

IE201 : Data Analytics, AI/ML LAB

<table>
<tr><td>Credits</td><td>L:0 T: 0 P: 3 C: 3</td></tr>
<tr><td>Prerequisites topics</td><td>Programming, basic Statistics</td></tr>
<tr><td>Lab topics/ sessions</td><td>Students will be various aspects related to data handling, data storage & retrieval from various sources (database, websites, etc), querying data, data cleaning, data manipulation, data summarization and data visualization

Data formatting: csv, arff, json, xml
Understanding and working with time series data,
Understanding and Working with image data , audio and video data
Processing and understanding text data, natural language data
Understanding and working with graph data, maps, spatio-temporal data

A broad list is given below
● Linear regression
● Classification: logistic regression, kNN, handling class imbalance
● Data augmentation: SMOTE
● Discriminant analysis: FDA, LDA
● Clustering - Hard, soft and hierarchical, K-means
● Dimensionality reduction, Principal component analysis, sparsity inducing regularizers
● Understanding basic neural networks (feed-forward nets, Convolutional neural nets, recurrent neural nets)
● Applications of ML: Sentiment analysis, object detection, question answering, recommendation systems.</td></tr>
<tr><td>References</td><td>1. Stuart Russell and Peter Norvig. Artificial Intelligence: A Modern Approach. Pearson, Fourth Edition, 2020.
2. Richard E. Neapolitan and Xia Jiang. Artificial Intelligence with an Introduction to Machine Learning, CRC Press, Second Edition, 2018.
3. Tom Mitchell. Machine Learning, McGraw Hill Education, First edition, 2017.</td></tr>
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IE204 : Feedbacks and Dynamics

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites	Linear Algebra
Course Topics	This course can cover modeling of dynamic (time varying) systems, with applications in business, production-inventory and socio-economic systems. Course topics include: ● Brisk review of Introduction to Dynamical Systems and Linear Dynamical Systems (Motivation through examples in business/ industrial settings); Modeling linear dynamical systems using ODEs; Solution characterization, solution methods for first, second, higher order ODEs; Characterizing higher order ODEs as linear systems ● Motivating examples of dynamical systems with feedback ● Laplace transforms. Transfer functions: Block diagrams, poles, zeros, delays ● Stability, regulation, tracking and Controllability of dynamical systems. ● Proportional, Integral, Derivative (PID) control ● Root locus design method: Perspective, procedure finding root locus, design using lead, lag, notch compensation ● Frequency-Response Design method: Frequency-response design method, Bode/ Nyquist plots ● State space method: System description, block diagrams, state equations and analysis ● Discrete systems and non-linear systems The second part can focus on capturing industrial and social systems using dynamics equations/ system dynamics methodology, including: ● Stock Management Structures and Industrial Dynamics ● Models for social systems and economics ● Simulation of linear and non-linear systems ● Simulation of Discrete-time and Continuous time systems
References	● Chi-Tsong Chen (1998) Linear System Theory and Design, 3rd edition, Oxford University Press ● Normal Nise, 2018,, Control Systems, Wiley India ● Morris W. Hirsch, Robert L. Devaney and Stephen Smale (2004) Differential Equations, Dynamical Systems, and an Introduction to Chaos, 2nd edition, Academic Press. ● John D. Sterman, 2000, Business Dynamics, McGraw Hill

IE202 : Digital Enterprise Systems Lab

Credits	L:0 T: 0 P: 3 C: 3
Prerequisites	None
Lab topics/ sessions	The lab teaches (hands-on) integration between the physical world and computer-based systems, helping to connect people, processes and devices. This includes lab session for experiential learning about ● Bar Coding, QR Codes, RFIDs, App based data collections ● IoT systems, develop and evaluate small IoT systems, which includes: sensors to get data, embedded systems to control/ process, wireless/wired transmission, store and process data. Use of actuators, Sensors, PLC controller/Use Raspberry Pi. ● Augmented Reality / Virtual Reality
References	

IE301 : Operations Analysis

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	Probability, statistics, some notions of optimisation.
Course topics/ subtopics	The aim of the course is to introduce students to concepts, models and methods for planning, designing, and operating manufacturing & service systems. Topics include: ● Resource planning, resource allocation ● Inventory control: Deterministic and Stochastic Models, Newsvendor models; Service levels; ● Scheduling ● Demand Forecasting ● Quality control & management, Six Sigma, Statistical Quality control ● Project Management: CPM and PERT ● Sustainable operations
References	● Steven Nahmias (2008) Production and Operations Analysis, 6th edition, McGraw-Hill. ● W. Hopp and M. Spearman (2008) Factory Physics, 3rd edition, McGraw-Hill ● Narayan Rangaraj, G. Raghuram, Mandyam Srinivasan, Supply Chain Management, McGrawHill, 2008 ● Joseph S. Martinich (2000) Production and Operations Management: An Applied Modern Approach, John Wiley & Sons ● R.J.Tersine, Principles of Inventory and Materials Management, 4th ed., Prentice Hall, 1994.

IE303 : Simulation

Credits	L3 T: 0 P: 0 C: 6
Prerequisites topics	Probability & Statistics Some knowledge of programming (any language; use of computers)
Course topics/ subtopics	Introduction to various types of simulation of dynamics and/or stochastic systems, including monte carlo methods, discrete event simulation, agent-baed modeling, system dynamics approach Understanding Steps in a Simulation study: model conceptualisation & scoping, input data collection, building simulation model, model verification and validation, design and conduct experiments, making valid observations from simulation results. Fundamental concepts of System Simulation: Monte Carlo simulation, Discrete event simulation systems in presence or absence of uncertainty; Generation & testing of random numbers. Generation of random variates. Input modeling; Fitting probability distributions; hypothesizing families of distributions, estimation of parameters, testing goodness of fit. Using software to analyze input data. Building Monte Carlo / Discrete event simulation models of various processes and systems. Use of general purpose languages such as Python/R/C++ (for MCS) and/or packages such as Anylogic, Flexsim, etc (for DES) to build simulation models. Simulation Output data analysis for a single system; statistical analyses for transient systems and systems in statistical equilibrium. Comparing alternative system configurations; confidence intervals, Using software to analyze simulation results. Model verification and validation. Advanced topics may include: Ranking and selection, Variance reduction techniques. Experimental design, sensitivity analysis and simulation-based optimization; Agent based modeling, System Dynamic methodology.
References	A. M. Law and W. D. Kelton (2000), Simulation Modeling and Analysis, 3rd Ed., McGraw Hill International - Industrial Engg. Series. J. Banks, J. S. Carson, B. L. Nelson and D. M. Nicol (2013), Discrete Event System Simulation,6th Ed., Pearson Education International Series. S. Ross (2012) Simulation, Academic Press. U Wilensky and W Rand (2015), An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, MIT Press

IE305 : Simulation Lab

Credits	L:0 T: 0 P: 3 C: 3
Prerequisites topics	Basic programming, Concurrent registration with Simulation course
Lab topics/ sessions	● Building simulation models of deterministic/ probabilistic; static/ dynamic models using software such as Python/ R/ other custom software. ● Use of general purpose languages such as Python/R/C++ (for Monte Carlo simulation) and/or packages such as Anylogic, Flexsim, etc (for discrete event/ agent based models) to build simulation models ● Implementing Monte Carlo Simulation models, monte carlo integration, random processes, markov chains. ● Discrete event simulation: Simulating Queueing models, single server, tandem queues, various queuing logics and decision logics. ● Conducting simulation experiments, Simulation based optimization. ● Visualizing simulation results, Building 2D and 3D animations. ● Simulation study of large systems such as hospitals, super markets, railway network, airport operations, manufacturing systems using all steps in simulation study, starting with problem conceptualization, data collection, input data analysis, model building, model verification and validation, conduct simulation experiments, make observations and recommendations, write a report. ● Advanced topics: Agent based models, system dynamics models, Introduction to augmented reality based simulation, virtual reality simulations, Interactive simulation, Digital Twins, Gaming models
References	● A. M. Law and W. D. Kelton (2000), Simulation Modeling and Analysis, 3rd Ed., McGraw Hill International - Industrial Engg. Series. ● J. Banks, J. S. Carson, B. L. Nelson and D. M. Nicol (2013), Discrete Event System Simulation,6th Ed., Pearson Education International Series. ● S. Ross (2012) Simulation, Academic Press. ● U Wilensky and W Rand (2015), An Introduction to Agent-Based Modeling: Modeling Natural, Social, and Engineered Complex Systems with NetLogo, MIT Press ● Dr. Andrei Borshchev, Ilya Grigoryev (2012) The Big Book of Simulation modeling.

IE307 : Stochastic Processes & Queueing Systems

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	IE1xx Probability & Statistics
Course topics/ subtopics	Models and techniques to deal with randomness that underlie many industrial and social systems. Emphasis on models, their properties and their applications ● Elementary stochastic processes: random walks, ● Markov chains: first step analysis, state classifications, invariant distributions, Finite state Markov chains, Chapman-Kolmogorov equations, Recurrent Markov Chains, positive & null recurrence, limiting state probabilities, Stationary distributions. ● Gambler's ruin, Random walk, Birth death chain ● Memory-less property of exponential random variables and related models & examples, Poisson processes. ● Queueing systems, Little law, PASTA ● Introduction to renewal processes, Machine repair problems, replacement problems.
References	[1]Sheldon Ross, Probability Models,10th Edition, Academic Press, 2010 [2] S. M. Ross, Stochastic processes, 2nd Edition, 1996, John Wiley, New York [3]D.P. Bertsekas and John N. Tsitsiklis, Introduction to Probability, 2002 [4]R. W. Wolff, Stochastic modeling and the theory of queues, 1989, Prentice Hall Inc., Engle-woodCliffs [5]Hoel, Port, Stone, Introduction to Stochastic Processes [6]Jean Jacod and Philip Protter, Probability Essentials, Springer, 2004. [7] James Norris, Markov Chains, CUP, 1998

IE302 : Logistics and Supply Chains

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	Operations Analysis, probability & Statistics, Optimisation
Course topics/ subtopics	Components of a supply chain. Supply chain structure. Decisions in Supply chains. Facility location / allocation models. Facility location under uncertainty Inventory management under multi-player settings, risk pooling Global supply chains. Sourcing decisions. Measures of effectiveness of supply chain performance. Transport of commodities. Freight modes, Economic batch size of movement, hub and spoke networks, First mile, line haul and last mile of movement. Multi-modal freight transportation, Vehicle planning and routing. Crew planning. Pricing and Revenue Management Information feedbacks and Bullwhip Sustainable Supply Chains: Reverse flows, reuse, recycle, remanufacture etc.
References	• Chopra and Meindl, Supply Chain Management: Strategy, Planning and Operations, 6th ed, 2016 • Janat Shah, Supply Chain Management, Text & Cases, 2016. • Simchi-Levi, D. P. Kaminski and E. Simchi-Levi (2003), Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies, (2nd Edition) Irwin, McGraw-Hill. • G. Raghuram and N. Rangaraj [Editors] (2000) Logistics and Supply Chain Management: Cases and Concepts, Macmillan, New Delhi. • Shapiro J. (2001), Modelling the Supply Chain, Duxbury Thomson Learning • Narayan Rangaraj, G. Raghuram, Mandyam Srinivasan, Supply Chain Management, McGrawHill, 2008

IE304 : Risk & Uncertainty

Credits	L:3 T: 0 P: 0 C: 6
Prerequisites topics	None
Course topics/ subtopics	Decision theory provides a rational framework for choosing between alternative courses of action when the consequences resulting from this choice are imperfectly known. This course introduces the idea of decision making in business settings (industrial and service systems) and other settings when the outcomes of these actions are known as well as unknown. 1. Decision making under certainty 2. Decision making under uncertainty including decision trees, min-max criteria 3. Expected utility 4. Risk and risk aversion 5. Subjective Probability 6. Group decision like AHP, ANP etc and social choice
References	1. Simon French, Decision Theory: An Introduction to Mathematics of Rationality, John Wiley & Sons, 1988. 2. Howard Raiffa, Decision Analysis: Introductory Lectures on Choices under Uncertainty, Addison Wesley, 1970. 3. Itzhak Gilboa, Making Better Decisions: Decision Theory in Practice, Wiley-Blackwell, 2011. 4. D. V. Lindley, Making Decisions, John Wiley & Sons, 1985. 5. Martin Peterson, An Introduction to Decision Theory, Cambridge University Press, 2017. 6. Michael D Resnik, Choices: An Introduction to Decision Theory, University of Minnesota Press, 2000. 7. Peter C Fishburn, Foundations of Expected Utility Theory, Springer, 1982.

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