NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI - 620 015

M.Tech. DEGREE

in

Industrial Engineering and Management

SYLLABUS

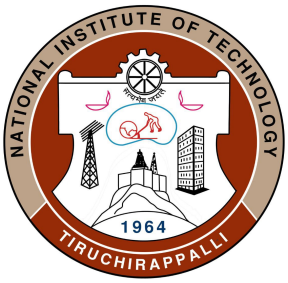
FOR

CREDIT BASED CURRICULUM

OPERATIVE FOR STUDENTS FROM 2015-2016 ADMISSION

4 SEMESTER PROGRAMME

CODE : PR



DEPARTMENT OF PRODUCTION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY: TIRUCHIRAPPALLI - 620 015
DEPARTMENT OF PRODUCTION ENGINEERING
M. Tech. INDUSTRIAL ENGINEERING & MANAGEMENT

Department Vision

To establish a world class academy for Manufacturing and Industrial Engineering

Department Mission

- Curriculum development with state-of-the-art technologies.
- Pursue research interests of manufacturing and industrial engineering.
- Consultancy in design, manufacturing and industrial engineering
- Industry-Institute interaction
- Equipping Laboratories with state-of-the-art equipment.

Programme Educational Objectives (PEOs):

PEO 1: Graduates of the programme will be capable of integrating Engineering fundamentals and advanced Industrial Engineering concepts.
PEO 2: Graduates of the programme will be professionally competent for gainful employment in Industrial Engineering and Management functions and sustain future challenges.

Programme Outcomes (POs):

M.Tech. – Industrial Engineering &Management		
	Attributes	**Programme Outcomes** On successful completion of the programme, the graduates will be able to
1	Scholarship of Knowledge	Acquire in-depth knowledge of industrial engineering with an ability to define, evaluate, analyse and synthesize existing and new knowledge.
2	Critical Thinking	Analyse complex real time industrial engineering problems critically, apply independent judgement for synthesizing information to make intellectual and/or creative advances for conducting research.
3	Problem Solving	Conceptualize and solve industrial engineering problems and evaluate potential solutions after considering economic and eco-friendly factors.
4	Research Skill	Develop scientific/technological knowledge in industrial engineering domain through literature review and design and analysis of experiments.
5	Usage of modern tools	Apply tools for modelling and simulation of complex system, life cycle assessment, ergonomic assessment, supply chain assessment and data analysis.
6	Collaborative and multi-disciplinary work	Perform collaborative-multidisciplinary industrial engineering research, through self-management and teamwork.

7	Project Management and Finance	Apply engineering and management principles to manage real time projects considering economical and financial factors.
8	Communication	Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.
9	Life-long Learning	Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.
10	Ethical Practices and Social Responsibility	Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.
11	Independent and Reflective Learning	Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI
DEPARTMENT OF PRODUCTION ENGINEERING
M. Tech (Industrial Engineering & Management)
Total minimum credits required: 66
(Operative for students from 2015-2016 admission)

CODE	Semester 1	L	T	P	C	CODE	Semester 2	L	T	P	C
PR651	Data Analytics	3	1	0	4	PR652	Quality & Reliability Engineering	3	0	0	3
PR653	Advanced Operations Research	2	1	0	3	PR654	Modeling and Simulation	2	1	0	3
PR655	Analysis and Control of Manufacturing Systems	3	0	0	3	PR656	Supply Chain Management	3	0	0	3
-----	**Elective I**	3	0	0	3	-----	**Elective IV**	3	0	0	3
-----	**Elective II**	3	0	0	3	-----	**Elective V**	3	0	0	3
-----	**Elective III**	3	0	0	3	-----	**Elective VI**	3	0	0	3
PR657	Data Analytics Lab	0	0	3	2	PR658	Simulation Lab	0	0	3	2
PR659	Operations Management Lab	0	0	3	2	PR660	Supply Chain Management Lab	0	0	3	2
Total		**17**	**2**	**6**	**23**	**Total**		**17**	**1**	**6**	**22**

CODE	Semester 3	L	T	P	C	CODE	Semester 4	L	T	P	C
PR691	Project Work – Phase I	0	0	24	**9**	PR692	Project Work – Phase II	0	0	24	**12**

LIST OF ELECTIVES

CODE	INDUSTRIAL ENGINEERING STREAM	L	T	P	C	CODE	MANAGEMENT STREAM	L	T	P	C
PR661	Industrial Engineering and Productivity Management	3	0	0	3	PR672	Project Management	3	0	0	3
PR662	Intelligent Manufacturing Systems	3	0	0	3	PR673	Financial Management	3	0	0	3
PR663	Research Methodology	3	0	0	3	PR674	Marketing Management	3	0	0	3
PR664	Design and Analysis of Experiments	3	0	0	3	PR675	Total Quality Management & Six Sigma	3	0	0	3
PR665	Enterprise Resource Planning	3	0	0	3	PR676	Human Resource Management	3	0	0	3
PR666	Lean and Agile Manufacturing	3	0	0	3	PR677	Decision Support Systems	3	0	0	3
PR667	Facilities Planning and Design	3	0	0	3	PR678	Knowledge Management	3	0	0	3
PR668	Production Management Systems	3	0	0	3	PR679	Product Life Cycle Management	3	0	0	3
PR669	Advanced Optimization techniques	3	0	0	3	PR680	Technology Management	3	0	0	3
PR670	Work Design and Ergonomics	3	0	0	3	PR681	Multi-Criteria Decision Making Techniques	3	0	0	3
PR671	Sustainable Manufacturing	3	0	0	3		**Common Electives with M.Tech. Manufacturing Tech.**				
						PR630	Product Design and Development	3	0	0	3

SEMESTER 1

PR651 DATA ANALYTICS

L	T	P	C
3	1	0	4

COURSE OUTCOMES:

1. Recognize the importance of data analytics
2. Exhibit competence on data analytics packages
3. Apply solution methodologies for industrial problems

Introduction to Multivariate Statistics-Degree of Relationship among Variables-Review of Univariate and Bivariate Statistics-Screening Data Prior to Analysis-Missing Data, Outliers, Normality, Linearity, and Homoscedasticity.

Multiple Regression- Linear and Nonlinear techniques- Backward-Forward-Stepwise-Hierarchical regression-Testing interactions (2way interaction) - Analysis of Variance and Covariance (ANOVA & ANCOVA) - Multivariate Analysis of Variance and Covariance (MANOVA & MANCOVA).

Logistic regression: Regression with binary dependent variable -Simple Discriminant Analysis-Multiple Discriminant analysis-Assessing classification accuracy- Conjoint analysis (Full profile method).

Principal Component Analysis -Factor Analysis- Orthogonal and Oblique Rotation-Factor Score Estimation-Multidimensional Scaling-Perceptual Map-Cluster Analysis (Hierarchical Vs Nonhierarchical Clustering).

Latent Variable Models an Introduction to Factor, Path, and Structural Equation Analysis- Time series data analysis (ARIMA model) – Decision tree analysis (CHAID, CART) - Introduction to Big Data Management.

References

1. Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. "Multivariate data analysis", (7^{th} edition). Pearson India. 2015
2. Tabachnick, B. G., & Fidell, L. S., "Using multivariate statistics", (5^{th} edition). Pearson Prentice Hall, 2001
3. Gujarati, D. N. , "Basic econometrics", Tata McGraw-Hill Education, 2012
4. Malhotra, N. K., " Marketing research: An applied orientation", 5/e. Pearson Education India, 2008
5. Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. " Applied multiple regression/correlation analysis for the behavioral sciences", Routledge., 2013
6. Han, J., Kamber, M., & Pei, J. "Data mining: concepts and techniques: concepts and techniques", Elsevier, 2011

PR653 ADVANCED OPERATIONS RESEARCH

L	T	P	C
2	1	0	3

COURSE OUTCOMES:

1. Make decisions in certainty / uncertainty conditions
2. Formulate models and solve real time problems
3. Apply advanced OR techniques to confront industrial requirements

Linear programming- Simplex method – Big M method – Two phase method cases - Goal programming. Duality, sensitivity analysis-Changes in right- hand side constants of constraints-changes in objective function co-efficient-adding a new constraints-adding a new variable.

Dual simplex method- Generalized simplex algorithm –Integer programming algorithm - Cutting plane algorithm- Branch and Bound technique – Zero-one implicit enumeration algorithm.

Deterministic dynamic programming –Recursive nature of computations in DP - Applications of dynamic programming - Cargo loading model – Work force size model – Equipment replacement model-Inventory model.

Network models - Shortest path model – Maximal flow problem - Crashing of project network – Resource leveling & Resource allocation technique.

Unconstrained nonlinear algorithms-Constrained algorithms- Separable programming -Quadratic programming-Geometric programming-Stochastic programming.

References

1. Handy M.Taha, “Operations Research, an introduction”, 7th edition, PHI, 2003.
2. Don T.Phillips, A.Ravindran & James Solberg, Operations Research: Principles and practice, John Wiley, India, 2006.
3. G.Srinivasan , “Operations Research Principles and Applications” ,PHI 2008
4. Panneerselvam ,R, "Operations Research”, Prentice – Hall of India, New Delhi,2002

PR655 ANALYSIS AND CONTROL OF MANUFACTURING SYSTEMS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the importance of production management
2. Classify various models
3. Solve industrial problems involved in inventory, MRP and scheduling

Basics of Product management – Forecast models, errors, tracking signals.

Inventory costs – types of systems – policies – Analysis & static models

Concept of aggregate production planning – strategies – Charting techniques – Problems Value stream management

MRP concepts – Problems – Lot sizing – techniques

Scheduling concepts – Various types of scheduling – Methods and tools to solve scheduling problems – Assembly line balancing problems

References

1. Elsayed A. Elsayed and Thomas O. Boucher, "Analysis and Control of Production Systems",Prentice Hall, 1994.
2. Monks J.G., "Operations Management, John Wiley, 1992.
3. Buffa.E.S. and Sarin, R.K. ,"Modern production /Operations Management", John Wiley & Sons, 1994.
4. Panneerselvam.R. Production and Operations Management, PHI, 2005.

PR 657 DATA ANALYTICS LAB

L	T	P	C
0	0	3	2

The objective of this lab is to enable students to have exposure on Data Analytics using SYSTAT, SPSS and GaBi.

1. Linear Regression and Correlation
2. Testing of Hypothesis – I & II
3. Analysis of Variance (ANOVA)
4. Factor analysis
5. Life Cycle Assessment of products
6. Cluster Analysis
7. Performance Measurement of Industrial systems

PR 659 OPERATIONS MANAGEMENT LAB

L	T	P	C
0	0	3	2

The objective of the lab is to have practical exposure on operations management packages like OM Expert, CPLEX, LINDO, GAMS, TORA extra and also to study on the ergonomic aspects of human evaluation.

1. Forecasting Models
2. Linear Programming Problem
3. Transportation Model
4. Inventory Models
5. Scheduling Case studies
6. Material Requirements Planning
7. Project management
8. Facilities layout
9. Ergonomics Study
    a. Performance rating using stop watch
    b. Peg board experiment
    c. Time study trainer
    d. Fitness study using treadmill
    e. Fitness study using ergo cycle

SEMESTER 2

PR 652 QUALITY AND RELIABILITY ENGINEERING

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Summarize the fundamentals and significance of Quality
2. Develop control charts for variables and attributes
3. Implement kaizen techniques for improved production environment

Basics of quality – Process capability analysis – Quality Gurus and their philosophies

Quality standards – ISO 9000 series and 14000 series

Design of experiments – ANOVA analysis – Reliability – MTBF – MTTR- Markov models for reliability Acceptance sampling by variables and attributes – ASN – ATI – AOQL - IS2500 plans – MIL STD 105E

Control charts for variables and attributes - Taguchi methods, cases

Concurrent engineering Quality function deployment – FMEA – Quality circles - Total quality management –Kaizen

References

1. Douglas, C. Montgomery, "Introduction to Statistical Quality Control", 2nd Edition, John Wiley & Sons, 2001.
2. Smith, D.J. "Reliability Maintainability and Risk; Practical methods for engineers", Butterworth-Heinemann, New Delhi, 2001
3. Grant, E.L. and Leavenworth, R.S., "Statistical Quality Control", TMH, 2000.

PR654 MODELING AND SIMULATION

L	T	P	C
2	1	0	3

COURSE OUTCOMES:

1.Develop Manufacturing Models of Discrete event systems
2.Generation of Uncertainty using Random numbers and Random Variates
3.Perform Input, Output Analysis: Verification & Valediction of Models and Optimization

Introduction to systems and modeling - discrete and continuous system - Monte Carlo Simulation. Simulation of Single Server Queuing System. Simulation of manufacturing shop Simulation of Inventory System

Random number generation Properties of Random Numbers –Generation of Pseudo Random Numbers –Techniques –Tests for Random Numbers

Random variates-Inverse Transform Technique –Direct Transform Techniques Convolution Method Acceptance Rejection Technique– Routines for Random Variate Generation

Testing -Analysis of simulation data-Input modeling – verification and validation of simulation models – output analysis for a single model.

Simulation languages and packages-Case studies in WITNESS; FLEXSIM, ARENA, SIMQUICK-Simulation based optimization-Modeling and Simulation with Petrinets-case studies in manufacturing systems

References

1. Jerry Banks & John S.Carson, Barry L Nelson, “Discrete event system simulation” ,Prentice Hall
2. Law A.M, “Simulation Modelling and Analysis”, Tata Mc Graw Hill
3. NarsinghDeo, “ System Simulation with Digital Computer”, Prentice Hall
4. Pidd, M, “Computer Simulation in Management Science”, John Wiley & Sons, Inc.

PR656 SUPPLY CHAIN MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the major building blocks, major functions, major business processes, performance metrics, and major decisions in supply chain networks
2. Summarize the foundation for design and analysis of supply chains and synthesize advanced and specialized concepts, principles and models for operational and strategic improvement
3. Analytically examine the supply chain of organizations and measure performance improvement

Introduction to supply chain management - Supply Chain Performance: Achieving Strategic Fit and Scope - Supply Chain Drivers and Metrics

Planning in Supply chain - Demand Forecasting in a Supply Chain - Aggregate Planning in a Supply Chain – Inventories in supply chain

Designing the Supply chain network – Distribution networks – Transportation networks - Network Design in an Uncertain Environment - supply chain optimization

Managing cross-functional drivers in supply chain - Sourcing Decisions in a Supply Chain - Pricing and Revenue Management in Supply Chain - Information Technology in Supply Chain - Coordination in Supply Chain

Modern Supply chain management - Reverse supply chain strategies – Green and sustainable practices of Supply chain – Supply chain cases

References

1. Sunil Chopra And Peter Meindl, “Supply Chain Management, strategy, planning, and operation” 6/e – PHI, second edition, 2014
2. V.V. Sople, “Supply Chain Management, text and cases”, Pearson Education South Asia,2012
3. Janat Shah, “Supply Chain Management, text and cases”, Pearson Education South Asia,2009
4. Balkan Cetinkaya, Richard Cuthbertson, Graham Ewer, “Sustainable Supply Chain Management: Practical ideas for moving towards best practice”, Springer, 2011
5. Jeremy F.Shapiro, Thomson Duxbury, “Modeling the Supply Chain”, 2002.

PR 658 SIMULATION LAB

L	T	P	C
0	0	3	2

(Packages: ARENA, Flexsim, QUEST, Simquick &Witness and other emerging packages, Programming in C and Matlab)

LIST OF EXERCISES

1. Random Number Generation approaches
2. Random Variate Generation
3. Simulation of Manufacturing Shop
4. Simulation of Multiple Servers Queuing System
5. Simulation of Supply Chain Inventory System
6. Simulation of Batch Production System
7. Simulation of Multi Machine Assignment System
8. Simulation of Manufacturing and Material Handling Systems
9. Simulation of a Shop Floor
10. Simulation of Material Handling Systems

PR 660 SUPPLY CHAIN MANAGEMENT LAB

L	T	P	C
0	0	3	2

The objective of this lab is to enable students to understand the practical applications of Supply Chain Management concepts.

1. Network design and operations
2. Designing and planning transportation networks
3. Designing and planning distribution networks
4. Value Stream Mapping – Development of Current State Map and Future State Map
5. Decision Making in Supply Chains
6. Lean, agile and leagile supply chains
7. Supply chain restructuring
8. Supply chain performance measures
9. Inventory optimization in supply chain
10. Forecasting models in supply chain

Electives

INDUSTRIAL ENGINEERING STREAM

PR661 INDUSTRIAL ENGINEERING AND PRODUCTIVITY MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Define and understand basic Productivity Concepts, Productivity Measurement Approaches of the Organizations.
2. Perform Work design and facility planning.
3. Outline the basics of Value Engineering (VE) and System Engineering.

Productivity: Concept, Productivity improvement factors, Productivity appraisal, productivity analysis in the enterprise- The Kurosawa structural approach, Lawlor's approach, Gold's approach, Quick Productivity Appraisal approach (QPA), Inter-Firm Comparison (IFC).

Work Design: Work study, Method study, Work measurement, Standard output, Time study, Work sampling, Process analysis.

Facility Layout: Principles of layout and facilities planning, Material flow patterns, Material handling systems, Types of material handling equipment.

Value Engineering: Fundamental concepts and applications of value engineering, Function Analysis System Technique.

Systems Engineering: Introduction to Systems Engineering, Management Information System, Phases in System Engineering, System Life Cycle, System Maintenance.

References

1. Prokopenko, J. "Productivity Management, A Practical Handbook", International Labour Organisation, 1992.
2. ILO, "Introduction to Work Study", George Kanawaty,4th revised edition, Universal Book Corporation 2007.
3. Apple, J.M. "Plant layout and materials handling", Ronald Press Company, Newyork, 1977.
4. Tutty Herald G, "Compendium on Value Engineering", Indo-American Society, 1983.
5. Andrew P Sage & James E Armstrong, "Introduction to Systems Engineering", Wiley series (2000).

PR662 INTELLIGENT MANUFACTURING SYSTEMS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Apply various knowledge based techniques
2. Practice diagnosis and trouble shooting
3. Adopt intelligent system

Basic concepts of Artificial intelligence and expert systems - System Components - System architecture and Data flow – System Operations.

Knowledge based systems - knowledge representation – knowledge acquisition and optimization - Knowledge based approaches to design mechanical parts and mechansims and design for automated assembly.

Knowledge based system for material selection – Intelligent process planning system. Intelligent system for equipment selection - Intelligent system for project management & factory monitoring.

Scheduling in manufacturing – scheduling the shop floor – Diagnosis & trouble shooting.

The role of Artificial Intelligence in the factory of the future – Intelligent systems.

References

1. Kenneth R.Baker, “Introduction to sequencing and scheduling”, John Wiley & Sons, New York, 2000.
2. Richard W. Conway, William L.Maxwell and Louis W. Miller, “Theory of Scheduling”, Dover Publications, 2003.

PR663 RESEARCH METHODOLOGY

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Choose and apply appropriate techniques.
2. Adopt different multi criteria decision making methods for prospective research
3. Adopt different optimization techniques to identify the suitable process parameters

Introduction- Hypothesis Testing, Multi criteria decision making-Simple Additive Weighting (SAW) Method-Weighted Product Method (WPM)

Analytic Hierarchy Process (AHP) Method-Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method-(VIKOR)-Outranking – PROMETHEE-ELECTRE

Optimization traditional, non-traditional- multi objective optimization-classical weighted sum, goal programming-non-traditional-

Multi objective GA, MOPSO, Intelligent decision making tools ANN, Fuzzy logic

Introduction to Matlab, C++

References:

1. Etter, D. Kuncicky, M, Hull, D. “Introduction to Matlab7”, Prentice Hall, 2004
2. Donald H.McBurney, “Research Methods”, Thomson Asia Pvt. Ltd, Singapore , 2002
3. Belton, V., Stewart, T.J. 2003. “Multiple Criteria Decision Analysis: An Integrated Approach”, Kluwer Academic Publishers, Dordrecht.
4. Deb. K. “Multi objective optimization using evolutionary algorithms”, Wiley , 2001

PR664 DESIGN AND ANALYSIS OF EXPERIMENTS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the practical implications of Design of experiments
2. Adopt ANOVA techniques to identify sufficient factors
3. Apply Taguchi techniques to conduct experiments in research work

Introduction- Planning of experiments – Steps – Need, Terminology: Factors, levels, variables, experimental error, replication, Randomization, Blocking, Confounding.

Single Factor Experiments- ANOVA - Sum of squares – Completely randomized design, Randomized block design, effect of coding, Comparison of treatment means – Newman Kuel's test, Duncan's Multiple Range test, Latin Square Design.

Factorial Experiments-Main and interaction effects –Two and three Factor full factorial Designs, 2^k designs with Two and Three factors- Yate's Algorithm

Special Experimental Designs- Blocking and Confounding in 2^k design

Taguchi Techniques- Fundamentals of Taguchi methods, Quality Loss function, orthogonal designs, application to Process and Parameter design.

References

1. Montgomery, D.C. "Design and Analysis of Experiments", John Wiley and Sons, 5th Edition,2002.
2. Hicks,C.R. "Fundamental concepts in the Design of Experiments", Holt, Rinehort and Winston, 2000.
3. Bagchi, T.P. "Taguchi Methods explained", PHI, 2002.
4. Ross, P.J. "Taguchi Techniques for quality Engineering", Prentice Hall, 2000.

PR665 ENTERPRISE RESOURCE PLANNING

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Summarize basic concepts, tools and techniques of Enterprise Resource Planning.
2. Describe the key implementation issues of ERP.
3. Reorganize the current and future trends in ERP.

Introduction to ERP: Enterprise – An Overview Integrated Management Information, Business Modeling, Integrated Data Model, Benefits of ERP,ERP and Related Technologies, Business Process Reengineering (BPR), Data Warehousing, Data Mining, OLAP, SCM.

ERP Implementation: ERP Implementation Lifecycle, Implementation Methodology, Organizing the Implementation, Vendors, Consultants and Users, Contracts with Vendors, Consultants and Employees, Project Management and Monitoring.

ERP Modules: Business Modules- Manufacturing, Materials Management, Finance, Plant Maintenance, Quality Management, Human Resources and Marketing.

ERP Market: ERP Market Place, SAP AG, PeopleSoft, Baan, JD Edwards, Oracle, QAD, SSA, Enterprise Integration Applications (EIA), ERP and E-Commerce, ERP and Internet.

ERP Present and Future: Future Directions and Trends in ERP.

References

1. Alexis Leon, “ERP demystified”, Tata McGraw–Hill publishing company Ltd., New Delhi, 2002.
2.Brady, “Enterprise Resource Planning”, Thomson Learning, 2001.
3.S.Sadagopan, “ERP: A Managerial perspective”, Tata McGraw–Hill publishing company Ltd., New Delhi, 1999.
4.Vinod Kumar Garg and Venkitakrishnan N K, “Enterprise Resource Planning – Concepts and Practice”, PHI, New Delhi, 2003.
5. Mary Sumner, “Enterprise Resource Planning”, Pearson Education, 2007.

PR666 LEAN AND AGILE MANUFACTURING

L	T	P	C
3	0	0	3

COURSE OUTCOMES

1. Describe the principles of lean and agile manufacturing
2. Recognize the potential applications of lean and agile manufacturing
3. Apply the tools/techniques of lean and agile manufacturing to industrial problems

Introduction to Lean Manufacturing, Comparison of Mass Manufacturing and Lean Manufacturing, Lean Principles, Types of Wastes – Seven basic categories, Types of activities – Value Added, Non Value Added and Necessary but Non Value Added activities, Examples

Primary Tools of Lean Manufacturing- 5S, Process Mapping and Value Stream Mapping, Work Cells, Total Productive Maintenance – Principle, Procedural steps and Advantages- Secondary Lean Tools.

Lean rules, Training and Implementation for lean systems, How to succeed with lean manufacturing, Leanness assessment – Indicators, methods and illustrative example.

Fundamentals of Agile Manufacturing, Agile Principles, Conceptual models of Agile Manufacturing, Product Development Strategies for agility, Developing the agile enterprise, Managing People in agile organizations.

Strategic approach to agile manufacturing, Information Technology applications in Agile Manufacturing, Assessment of agility – Activity Based Costing - Application Case studies on Lean and Agile Manufacturing.

References

1. Montgomery, J.C and Levine, L. O., "The transition to agile manufacturing – Staying flexible for competitive advantage", ASQC Quality Press, Wisconsin, 1996.
2. Gopalakrishnan "Simplified Lean Manufacture – Elements, Rules, Tools and Implementation", PHI Learning Private Limited, New Delhi, India, 2010.
3. Hobbs, D.P. "Lean Manufacturing Implementation", Narosa Publisher, 2004.
4. Devadasan, S.R., Sivakumar, V., Mohan Murugesh, R., Shalij, P, R. "Lean and Agile Manufacturing: Theoretical, Practical and Research Futurities", Prentice Hall India, 2012.

PR667 FACILITIES PLANNING AND DESIGN

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Assess the value of facility planning on the strategy of a firm.
2. Describe the product, process and schedule design and their interaction with facility planning and develop a systematic facility layout
3 Explain design and analyze material handling used in the warehousing, manufacturing and supporting operations.

Facilities planning – need and objectives of facilities planning – facilities planning process – Facilities planning strategies, Facilities Location Analysis- Single facility location models- Multi-facility location problems

Facilities Layout design- product design – process design – schedule design - Space and Area Requirements of Facilities

Layout design procedure-Algorithmic approach – Computerized layout planning-
CRAFT, ALDEP and CORELAP

Group technology - Methods of grouping – Algorithms and models for Group technology – Line balancing

Material handling design – Material handling principles - Classification of material handling equipment - Material handling models

References:

1. Tompkins, J.A. and J.A.White, “Facilities planning”, John Wiley, 2010.
2. Richard Francis.l. and John A.White, “Facilities layout and location - An analytical approach”, PHI, 2002.
3. James Apple. M , “Plant layout and Material handling”, John Wiley, 1977.
4. Pannerselvam,R, “Production and Operations management”, PHI,2012
5. B. Mahadevan, “Operations management: Theory and Practice”,2nd Edition, Pearson education South Asia, 2010.

PR668 PRODUCTION MANAGEMENT SYSTEMS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the role of Production Management System.
2. Identify the recent trend of manufacturing like Just in Time (JIT) and Pull Push system.
3. Outline the basics of Value Engineering (VE).

Productivity: Productivity measurement models, Role of work study, Work measurement techniques, Ergonomics.

CIM and Production Management Systems: Capacity Requirement Planning (CRP), Master Production Schedule, MRP, MRPII, Lot sizing in MRP- Lot for lot, Economic order quantity, Periodic order quantity, Part period balancing.

Just in Time and Lean Operations: Characteristics of Lean systems for services and Manufacturing, Element of JIT manufacturing, Pull and Push method of work flow, Small lot sizes, Kanban system, Value stream mapping.

Introduction to optimized production technology (OPT) - OPT philosophy improvement tools- Requirement and assumption of OPT.

Value Engineering: Approaches of value analysis and engineering, effective organization for value work function analysis system techniques, FAST diagram, Case Study.

References

1. Browne, Hairnet &Shimane, "Production management – A CIM perspective", Addison Wesley publication Co., 1989.
2. Orlicky, J; "Material Requirement Planning: the new way of life in production and inventory management", McGraw Hill, 1975.
3. Parker, D.E., "Value engineering theory", Sundaram publishers, 2000.
4. Panneerselvam, R. "Production and Operation management", PHI, 2005.
5. Schonlenger, R.L., "Japanese manufacturing techniques: 9 hidden lessons simplicity", The Free press, 1982.

PR669 ADVANCED OPTIMIZATION TECHNIQUES

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Describe the Traditional optimization techniques and apply it in engineering field.
2. Distinguish between the Non Traditional optimization techniques and apply it in engineering field.

Introduction-Engineering Applications of Optimization-Statement of an Optimization Problem-Classification of Optimization Problems - Optimization Techniques

Classical Optimization Techniques- Single-Variable Optimization - Multivariable Optimization with No Constraints - Multivariable Optimization with Equality Constraints- Multivariable Optimization with Inequality Constraints- Transportation

Nonlinear Programming I: 1D Minimization Methods - Unimodal Function, Elimination Methods-Unrestricted Search, Exhaustive, Dichotomous Search- Interval Halving Method-Fibonacci Method- Golden Section Method, Interpolation Methods -Quadratic, Cubic Interpolation Method - Direct Root Methods -Newton Method-Quasi-Newton, Secant Method

Nonlinear Programming II: Unconstrained Optimization Techniques -Direct Search Methods - Indirect Search (Descent) Methods, Non-linear Programming III: Constrained Optimization Techniques- Direct Methods-Indirect Methods, Geometric Programming, Dynamic Programming, Integer Programming -Integer Linear Programming - Stochastic Programming.

Modern Methods of Optimization - Genetic Algorithms -Simulated Annealing -Particle Swarm Optimization -Ant Colony Optimization -Optimization of Fuzzy Systems - Neural-Network-Based Optimization, Practical Aspects of Optimization

References

1.Kalyanmoy Deb, “Optimization for Engineering design – algorithms & examples”, PHI, New Delhi, 1995.
2.SingiresuS.Rao, “Engineering optimization – Theory and practices”, John Wiley and Sons, 1998.
3.Garfinkel, R.S. and Nemhauser, G.L., “Integer programming”, John Wiley & Sons, 1972.

PR 670 WORK DESIGN AND ERGONOMICS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. List the methods for productivity measurements and improvements
2. Analyze the work study methods for managing resources
3. Analyze the ergonomic methods for workplace design

Introduction to work study - Productivity – productivity measures-productivity measurement models-Kurosawa structural approach, Lawlor's approach, Gold's approach Quick Productivity Appraisal approach (QPA) / American Productivity Centre (APC) model-scope of work study for improving productivity

Motion and time study - Work methods design. Motion study-process analysis – process chart – flow diagram – assembly process chart –Man and machine chart – two handed process chart - Micro motion and memo motion study.

Work measurement and its methods. Determining time standards from standard data and formulas -Predetermined motion time standards – Work factor system – methods time measurement, Analytical Estimation. Work sampling – Group Timing Technique- introduction to work study software

Measuring work by physiological methods – Heart rate measurement– measuring oxygen consumption– Establishing time standards by physiology methods.

Motion economy- Ergonomics practices – human body measurement – layout of equipment– seat design - design of controls and compatibility – environmental control – vision and design of displays. Design of work space, chair table.

References

1. Barnes, Raeph.M., "Motion and Time Study – Design and Measurement of Work ", John Wiley &sons, New York, 1990
2. Mc.Cormick, E.J., "Human Factors in Engineering and Design", McGraw Hill
3. ILO, "Introduction to Work study", Geneva, 1974

PR 671 SUSTAINABLE MANUFACTURING

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the importance of sustainable development
2. Exhibit competence on the usage and applicability of sustainability tools
3. Compute sustainability performance through the indicators

Concepts of sustainability and sustainable development – Need for sustainable development - Components of sustainability- Social, Economic, Environmental dimensions - Linkages between technology and sustainability - Sustainable Manufacturing –Scope, Need and Benefits.

Tools and Techniques of Sustainable Manufacturing – Environmental Conscious Quality Function Deployment, Life cycle assessment, Design for Environment, R3 and R6 cycles, Design for Disassembly -Sustainable Product Development – Various Phases.

EIA Methods –CML, EI 95 and 99, ISO 14001 EMS and PAS 2050 standards, Environmental Impact parameters - Interactions between energy and technology and their implications for environment and sustainable development.

Design for recycling – Eco friendly product design methods – Methods to infuse sustainability in early product design phases – Multi-Criteria Decision Making in Sustainability.

Frameworks for measuring sustainability- Indicators of sustainability – Environmental, Economic, Societal and Business indicators - Concept Models and Various Approaches, Product Sustainability and Risk/Benefit assessment– Corporate Social Responsibility.

LAB EXERCISES

Life Cycle Assessment of products using GaBi package

Sustainable Product Development – Developing environmentally friendlier products

REFERENCES

1. G. Atkinson, S. Dietz, E. Neumayer, — "Handbook of Sustainable Manufacturing". Edward Elgar Publishing Limited, 2007.

2. D. Rodick, "Industrial Development for the 21st Century: Sustainable Development Perspectives", UN New York, 2007.

3. Rogers, P.P., Jalal, K.F. and Boyd, J.A., "An Introduction to Sustainable Development", Earth scan, London, 2007.

4. P. Lawn, "Sustainable Development Indicators in Ecological Economics", Edward Elgar Publishing Limited.

5. S. Asefa, "The Economics of Sustainable Development", W.E. Upjohn Institute for Employment Research, 2005.

MANAGEMENT STREAM

PR672 PROJECT MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain the methods for project identification & appraisal
2. Define and plan a project within the constraints of the environment
3. Develop & analyze quantitative models for project selection & scheduling

Introduction **-** Project Management: An Overview – Types, Characteristics of Projects – Project life cycle. Identification of investment opportunities - Screening and Selection, Project Appraisal,

Market and demand analysis- market survey-demand forecasting methods-Technical analysis – manufacturing process, materials-product mix, plant location-project charts and layouts.

Financial analysis – cash flows for project appraisal- Investment evaluation using capital budgeting techniques - net present value, profitability index internal rate of return, payback period, accounting rate of return

Mathematical Techniques for project evaluation – Linear programming, goal programming, Network technique for Project Management – CPM, PERT, Multiple projects and constraints, scheduling.

Organization systems for project implementation- Work Breakdown-coordination and control- Project Management Soft wares

References

1. Prasanna Chandra, "Projects – Planning, Analysis, Financing, Implementation and Review", Tata McGraw Hill,4th Ed, 1997
2. S.Choudry "Project Management", Tata McGraw Hill,27th Ed, 2006
3. John M Nicholas, "Project Management for Business and Technology", 2nd edition, Pearson Education Asia, 2001

PR673 FINANCIAL MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Start and manage new business
2. Evaluate and monitor short term and long term investments
3. Evaluate and monitor current asset

Financial management – An overview - Nature, Scope, Objectives, Decisions -Management of current asset - Short and intermediate financing

Capital budget, Nature of capital budgeting- Identifying relevant cash flows - Evaluation Techniques: Payback, Accounting rate of return, Net Present Value, Internal Rate of Return, Profitability Index - Comparison of DCF techniques investment and evaluation

Financial and operating leverage - capital structure - Cost of capital and valuation - designing capital structure. Dividend policy - Aspects of dividend policy - practical consideration

Principles of working capital: Concepts, Needs, Determinants, issues and estimation of working capital - Accounts Receivables Management and factoring - Inventory management – Cash management – Working capital finance

Long term financing -Indian capital and stock market, New issues market Long term finance: Shares, debentures and term loans, lease, hire purchase, venture capital financing, Private Equity

References:

1. Bhattacharya, S.K. and John Deardon, "Accounting for Management – Text and Cases", Vikas Publishing
   House, New Delhi, 1996.
2. Charles, T.Horn Green – "Introduction to Management Accounting", Prentice Hall, New Delhi, 1996.
3. James, C.Van Horne, "Fundamental of Financial Management", Pearson Education, 12th Edition, 2002.
4. Prasanna chandra, "Financial Management theory and practice", TMH, Vth edition, 2001.

PR674 MARKETING MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Explain marketing concepts& segmentation factors
2. Classify various pricing methods
3. Explain various sales promotion aspects

Concepts in Marketing - Marketing Process, Marketing concepts, Environment-Buying Behaviour and Market Segmentation-factors, Motives, Types, Buying Decision, Segmentation factors, Demographic, Psychographic and Geographic Segmentation, Process, Patterns

Product Pricing and Marketing Research- Pricing, Decisions and Pricing Methods, Pricing Management-Marketing Planning and Strategy Formulation-Portfolio Analysis, BCG, GEC Grids

Advertising, Sales Promotion and Distribution-Impact, Goals, Types, Sales Promotion – Point of purchase, Unique Selling propositions, Characteristics, Wholesaling, Retailing, Channel Design, Logistics Modern Trends in Retailing.

References:

1. Kotler Philip, Kevin Lane Keller, "Marketing Management", 13th Ed., Pearson Education (Singapore) Pvt. Ltd., New Delhi, 2007.
2. Zikmund DAmico, "The power of Marketing", 7th edition, South Western , Thomson Learning Publications, 2006.
3. Michael J. Etzel, Bruce J. Walker, William J. Stanton, Ajay Pandit, "Marketing – concepts and cases", special Indian edition, McGraw Hill

PR675 TOTAL QUALITY MANAGEMENT AND SIX SIGMA

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Recognize the importance of TQM in industrial scenario
2. Competence to apply specific TQM tool for the problems
3. Execute various phases of Six Sigma for real time projects

Principles of Quality Management, Quality Management Gurus and their contributions, Introduction to Total Quality Management (TQM), Concepts of TQM, Obstacles to TQM implementation, Benefits of TQM implementation.

Basic and Advanced Quality Control tools, Quality Function Deployment, Failure Mode and Effect Analysis – Scope, steps, illustrative examples and applications.

ISO 9000 standards, ISO 9001:2008 Quality Management System – Eight clauses, Registration, Implementation steps, Quality Audit, Product and Process audit – Scope, Steps and Benefits

Introduction to Six Sigma, Six Sigma DMAIC and DMADV Methodologies, Six Sigma and Lean Management, Benchmarking.

Quality Costing – Cost categories, Prevention, Appraisal and Failure cost, construction of PAF model, TQM and Six Sigma in Service Sector, Application case studies of TQM and Six Sigma.

References

1. Dale H.Besterfield, “Total Quality Management”, Pearson Education Asia, (Indian reprint 2002)
2. John Bank, “The essence of Total Quality Management”, PHI 1993.
3. Logothetis N., “Managing for Total Quality – From Deming to Taguchi and SPC”, Prentice Hall of India Pvt. Ltd. 1996
4. Thomas Pyzdek, “Six Sigma Hand book”, Tata McGraw-Hill, 2010
5. C.M.Creveling, L.Slutsky & D.Autis.Jr., “Design for Six Sigma”, Pearson education, 2003.

PR 676 HUMAN RESOURCE MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Evaluate and apply theories of social science disciplines to workplace issues
2. Select, develop, and motivate workers using HRM functional capabilities
3. Express analytical, communication, and decision making skills considering ethics

Individual Behavior-Personality –Attribute – Perception –Motivation Theories

Group Behavior-Group Dynamics, Group decision making, Inter personal Relations-Dynamics of Organizational Behavior- Organizational Climate–Organizational change –the Change Process & Change Management-

Human Resources Planning–HR audit, Recruitment-Selection-Interviews -Human Resources Development-Employee Training -Career Development-Performance Appraisal-Compensation-safety and Health-Employee Relation-Management Development.

Values and Ethics-Engineering as experimentation-Engineers as responsible experimenters Social Responsibility, and Sustainability.

References:

1. Stephen R. Robbins, “Organizational Behavior”, PHI, 1998.
2. Gary Dessler “Human resources Management” Prentice Hall of India 9th edn.2003
3. David A. Decenzo & Stephen R. Robbins, “Personnel/Human Resources Management”, PHI, 1997.
4. Fred Lutherans, “Organizational Behavior”, Oxford University Press, 2000.

PR677 DECISION SUPPORT SYSTEMS

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Define the importance of decisions in the work and the life and use DSS Software Tools
2. Evaluate the Success/Failure of Decision Support Systems
3. Discuss the advantages/disadvantages of different Types of decision support systems and analyze practical cases for different problems (technical, management)

DSS components- Data warehousing, access, analysis, mining and visualization-modeling and analysis-DSS development

Group support systems- enterprise DSS- supply chain and DSS-knowledge management methods, technologies and tools

Artificial intelligence and expert systems- Representation in logic and schemas, semantic networks, production rules and frames, inference techniques – DSS applications

References:

1. Efraim Turban and Jay E Aronson, Decision Support and Intelligent Systems, Pearson education Asia, Seventh edition, 2005
2. Elain Rich and Kevin Knight, Artificial intelligence, TMH, 2006
3. Vicki L. Sauter, Decision Support Systems for Business Intelligence John Wiley & Sons. Turban, Decision Support And Business Intelligence Systems, 8/E, Pearson Education India, 2011
4. Frada Burnstein, Clyde W. Holsapple., Handbook on Decision Support Systems Springer, 2008

PR678 KNOWLEDGE MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Appreciate the role and use of knowledge in organizations and institutions, and the typical obstacles that KM aims to overcome
2. Describe the core concepts, methods, techniques, and tools for computer support of knowledge management
3. Apply and integrate appropriate components and functions of various knowledge management systems

Knowledge society- Drivers of knowledge management-Intellectual capital- KM and learning organizations-Strategic alignment- Evaluation and strategic alignment

Infrastructural development and deployment- Role of CKO-Analyzing business environment-knowledge audit and analysis – designing KM team, system–Technology components- Intranet and Groupware solutions- tools for collaborative intelligence

Social networking-package choices- knowledge security-Integrating with web -based and internal operational & support systems- change management- reward systems- continuous improvement – Intellectual Property Rights.

References

1. Guus Schreiber, Hans Akkermans, “Knowledge Engineering and Management”, Universities Press, 2004
2. Elias M.Awad & Hassan M. Ghaziri, “Knowledge Management”, Pearson Education, 2004

PR679 PRODUCT LIFE CYCLE MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Recognize the importance of Product Life Cycle Management
2. Realize potential for Collaborative Product Development and digital manufacturing in contemporary manufacturing applications
3. Exhibit competence to develop PLM strategy and conduct PLM assessment

Introduction to Product Life Cycle Management (PLM)- Definition, PLM Lifecycle model, Need for PLM, Opportunities and benefits of PLM, Components and Phases of PLM, PLM feasibility study

PLM Concepts, Processes and Workflow - Characteristics of PLM, Environment driving PLM,PLM Elements, Drivers of PLM, Conceptualization, Design, Development, Validation, Production, Support of PLM.

Collaborative Product Development- Engineering vaulting, product reuse, smart parts, engineering change management, Bill of materials and process consistency, Digital mock-up and prototype development, design for environment, virtual testing and validation, marketing collateral

Digital Manufacturing – PLM Digital manufacturing, benefits manufacturing, manufacturing the first-one, Ramp up, virtual learning curve, manufacturing the rest, production planning

Developing a PLM strategy and conducting a PLM assessment- Strategy, Impact of strategy, implementing a PLM strategy, PLM initiatives to support corporate objectives. Infrastructure assessment, assessment of current systems and applications

References

1. Antti Saaksvuori, Anselmi Immonen, " Product Lifecycle Management", Springer, 2005
2. John Stark, "Product lifecycle management: 21st century paradigm for product realization", Springer 2006 London, 3rd printing -2006. 441 pp., ISBN: 1-85233-810-5.
3. Michael Grieves, "Product lifecycle management: Driving the next generation of Lean thinking", McGraw-Hill, 2006
4. Kari Ulrich and Steven D. Eppinger, "Product Design & Development", McGraw Hill International Edition, 1999

PR680 TECHNOLOGY MANAGEMENT

L	T	P	C
3	0	0	3

COURSE OUTCOMES:

1. Develop an awareness of the range, scope, and complexity of technological innovation, and the issues related to managing technological change.
2. Explain different approaches to managing innovation, with -criteria decision making techniques
3. Clearly identify drivers and barriers to technological innovation within an organization.

Definition-scope-components -Issues in managing new technology, Life cycle approach to technology management**-**Approaches to forecasting, Technology performance parameters.

Use of Experts in technology forecasting, planning technological process, Morphological analysis of a Technology system-Techno-Economic feasibility study

Application of multi-criteria decision making techniques in technologies evaluation and selection-AHP, fuzzy AHP-Modes of global technology transfer-Technology–Human Interface-

Organization structures and Technology Implementation issues in new technology – Technology Management issues in the context of lean, agile and sustainable systems – Intellectual Property Rights.

References

1. Joseph M. Putti, “Management – A Functional Approach”, McGraw Hill, 1997
2. Kenneth C. Lauden , “MIS: Organisation and Technology”, Prentice Hall, 1995
3. James A.Senn, “Information technology in Business”, Prentice Hall, 1995
4. Ronald J. Jordan, “Security analysis and Portfolio Management”, Prentice Hall, 1995

PR681 MULTI-CRITERIA DECISION MAKING TECHNIQUES

L	T	P	C
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COURSE OUTCOMES:

1. Recognize the importance of multi criteria decision making
2. Understand various MCDM methods
3. Apply MCDM methods for real life applications

Multi-Criteria Decision Making – An Overview – Classification of MCDM methods – Simple Additive Weighting method – Weighted Product method – Principle, steps and illustrative examples.

Network based MCDM methods – Analytic Hierarchy Process – Revised Analytic Hierarchy Process – Analytic Network Process – Principle, steps and illustrative examples.

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Outranking MCDM methods – PROMETHEE, ELECTRE, TOPSIS - Compromise Ranking method - VIKOR, ORESTE – DEMATEL – Principle, steps and illustrative examples.

Fuzzy based MCDM methods – Hybrid MCDM methods – Group Decision Making- Graph Theory and Matrix approach – Principle, steps and illustrative examples.

Goal Programming – Balanced Scorecard Approach - MCDM application areas – Case studies on application of MCDM techniques.

References

1. Belton, V., Stewart, T.J. “Multiple Criteria Decision Analysis: An Integrated Approach”, Kluwer Academic Publishers, Dordrecht, 2003.
2. Triantaphyllou, E., “Multi-Criteria Decision Making Methods: A Comparative Study”, Springer, 2010.
3. Pedrycz, W., Ekel, P., Parreiras, R., “Fuzzy Multi Criteria Decision-Making: Models, Methods and Applications”, John Wiley & Sons, 2011.
4. Kahraman, C., “Fuzzy Multi-criteria Decision Making: Theory and Applications with Recent Developments”, Springer, 2008.

Common Elective with M.Tech. Manufacturing Technology

PR 630 PRODUCT DESIGN AND DEVELOPMENT

L	T	P	C
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COURSE OUTCOMES

1. Understand the challenges and advancements of product development process
2. Execution of various phases of product development
3. Development of environmentally friendly products/processes

Product development process – various phases, Reverse engineering and redesigning product development process, Illustrations of product development process, S-curve, new product development.

Gathering customer needs, organizing and prioritizing customer needs, establishing product function, FAST method, establishing system functionality. Tear Down and Experimentation- Tear down method, post teardown report, benchmarking and establishing engineering specifications, product portfolios.

Generating Concepts- Information gathering, brain ball, C-sketch/6-3-5 method, morphological analysis, concept selection, technical feasibility, ranking, measurement theory.
Robust design, Design for Manufacture and Assembly, Axiomatic design, TRIZ, Value Engineering, Industrial design, Poka Yoke – Lean principles – Six sigma concepts.

Design for the Environment: DFE methods, life cycle assessment, weighted sum assessment method, techniques to reduce environmental impact – disassembly, recyclability, remanufacturing regulations and standards.

References

1. Kevin Otto and Kristin Wood, ―Product Design – Techniques in Reverse Engineering and New Product Development‖, Pearson Education, 2004.
2. Karl T Ulrich and Steven Eppinger, ―Product Design and Development‖, McGraw Hill, 2011, Fifth Edition.