**M.Tech. in Industrial Engineering**
Overall Credit Structure:
Core Courses : 12
Major Project (Core): 24 (12 +12)
Electives: 12
Total : 48

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SEM 1 | Probability and statistics **Core** 3-0-0 | Operations Research **Core** 3-0-0 | Industrial Engineering Systems **Core** 1-0-4 | Course from PLM track **Elective 1** 3-0-0 | | | Core=12+24 Elec=12 Tot=48 | |
| SEM 2 | Operations Planning and Control **Core** 3-0-0 | **Elective 2** 3-0-0 | **Elective 3** 3-0-0 | **Elective 4** 3-0-0 | | | | |
| SEM 3 | MTP1 **Core** (12 credits) | | | | | | No. of core courses = 4 No. of elective courses = 4 | |
| SEM 4 | MTP2 **Core** (12 credits) | | | | | | | |

Electives with suggested Tracks

- **Analytics and Optimization:**
  - Stochastic Modeling and Simulation
  - Advanced Operations Research
  - Optimization
  - Manufacturing Informatics
  - One or two electives from Dept of Math
- **Product Life Cycle Management:**
  - Quality Systems
  - Reliability Engineering
  - Value Engineering and Life Cycle Costing
- **Operations Management:**
  - Supply Chain Management
  - Logistics
  - Service System Design
  - Project Management
  - Enterpreneurship
  - Maintenance management
  - Electives from DMS

**Special Topics in IE**

Relevant electives from other specializations

- Automation
- CAM
- Machining

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | IE SEMINAR |
| **3.** | **L-T-P structure** | 0-0-2 |
| **4.** | **Credits** | 1 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Core |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | NA |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☒ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** Makarand Kulkarni, Nomesh B. Bolia, S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: The objective of the course is to train students in literature survey and presentation skills as well as develop an appreciation of the importance of seminars for research and development. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Depending on the student strength, the course coordinator will make a schedule for guest talks, literature review on topics chosen by students, and corresponding presentations by students. |

**15. Lecture Outline** *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
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| | COURSE TOTAL *(14 times 'L')* | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | Industry Expert Talks | 6 |
| 2 | Student Seminars | 22 |
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| | | |
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| | | |
| | COURSE TOTAL *(14 times 'P')* | 28 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| NA |

**19. Resources required for the course** *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | Videos demonstrating key principles, INFORMS subscription |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | Guest Speakers at Industry Site or Othwerwise |

**20. Design content of the course** *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | INDUSTRIAL ENGINEERING SYSTEMS |
| **3.** | **L-T-P structure** | 1-0-4 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | Lab course (MCP xxx) |
| **6.** | **Status** (*category* for *program*) | Core |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | MEL751 |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M. S. Kulkarni, N. Bolia, S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | No |

**13. Course objective** *(about 50 words)*:

The objective of the course is to teach students how to formulate and solve some of the common problems Industrial Engineering.

They will learn the theory behind a solution method in the class.

In the practical sessions, they will solve small size problems by hand and use software for solving bigger problems.

**14. Course contents** *(about 100 words) (Include laboratory/design activities)*:

Decision making under uncertainty (Pay-off tables, decision trees, utility theory etc.), Probability based methods for outcome prediction (Logistic regression, Bayesian belief networks, Monte Carlo simulation etc.), Multicriteria decision making (AHP, ANP, Graph theory etc.), System Simulation (through games like the Beer game for supply chain), Queuing theory games, Economic analysis (NPV, IRR etc. for

| | |
|---|---|
| | deterministic and stochastic scenarios), Algorithms (branch and bound, Metaheuristics etc.), Formulation of bigger optimization problems and solving using available solvers (eg. CPLEX). Shop-floor scheduling. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Decision making under uncertainty | 2 |
| 2 | Probability based methods for outcome prediction | 2 |
| 3 | Multicriteria decision making | 2 |
| 4 | System Simulation | 2 |
| 5 | Queuing theory games | 2 |
| 6 | Economic analysis | 2 |
| 7 | Shop-floor scheduling | 2 |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| | | |
| | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'L')* | | 14 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | Decision making under uncertainty | 8 |
| 2 | Probability based methods for outcome prediction | 8 |
| 3 | Multicriteria decision making | 8 |
| 4 | System Simulation | 8 |
| 5 | Queuing theory games | 8 |
| 6 | Economic analysis | 8 |
| 7 | Shop-floor scheduling | 8 |
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|---|---|---|
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| COURSE TOTAL *(14 times 'P')* | | 56 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| Handouts and the necessary material will be made available |

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | Matlab, R, CPLEX, Netica BBN, Arena, Expert Choice, AnyLogic |
| 19.2 | Hardware | PC, Laptop |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | 100% |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | OPERATIONS PLANNING AND CONTROL |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Core |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | MEL754 |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☒ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** Makarand Kulkarni, Nomesh B. Bolia, S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: The objective of the course is to expose students to the methods used by the industry to plan and control their operations. The course will also enable students to model the processes using fundamentals, and improve their performance. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Evolution of Scientific Management and Buzzwords, Inventory Management and Control, MRP and ERP, JIT, Modeling of Processes and Systems, Measuring and Improving Performance, Scheduling, Aggregate Production Planning, Facility Location |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction and Motivation | 3 |
| 2 | Inventory Management and Control | 8 |
| 3 | MRP-ERP | 4 |
| 4 | JIT | 4 |
| 5 | Modeling of processes | 3 |
| 6 | Measuring and Improving Performance | 4 |
| 7 | Scheduling | 9 |
| 8 | Aggregate Production Planning | 3 |
| 9 | Facility Location | 4 |
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| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
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| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| Factory Physics, W. Hopp and M. Spearman, McGraw-Hill, 2nd Edition<br><br>Supply Chain Management, S. Chopra and P. Meindl, Prentice Hall, 5th Edition<br><br>Interfaces - A Journal of the Institute for Operations Research and Management Science (INFORMS), subscribed by IIT Delhi, available on IITD library website. |

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | CPLEX, Anylogic |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | Videos demonstrating key principles, INFORMS subscription |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | Industry Visits to Appreciate Problems |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | OPERATIONS RESEARCH |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Core |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | MEL765 |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** Nomesh B. Bolia, Kiran Seth | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: To introduce students to the science of modeling and tools of Operations Research. The course will enable the students to model real life situations in various domains, and use mathematical tools to optimize decision making. Through a variety of case studies, students will appreciate the power of simple and often tractable tools of Operations Research. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: The art and science of modeling, Linear Programming, Solution methods including Simplex, Sensitivity Analysis, Shadow Pricing and Duality Theory, Integer Programming and Solution methods, Dynamic Programming with applications, Large Canonical problems such as Transportation Problem, Traveling Salesman Problem, Network Flow Problem, Case Studies. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction and Motivation | 2 |
| 2 | Linear Programming: Formulation with applications | 3 |
| 3 | Solving Linear Programs (Simplex, Revised Simplex), Sensitivity Analysis | 6 |
| 4 | Duality Theory | 6 |
| 5 | Integer Programming: Formulation | 3 |
| 6 | Solving Integer Programs | 2 |
| 7 | Dynamic Programming Theory and Applications | 5 |
| 8 | Large Canonical Problems: Transportation Problem, Traveling Salesman Problem, Network Flow Problem | 9 |
| 9 | Industry Scale Applications and Case Studies | 6 |
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| | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
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| | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.


Hillier, F. S. and Lieberman, G.J. Introduction to Operations Research. McGraw-Hill. 7th Edition. 2001.

Taha, H. Operations Research: An Introduction. Pearson Education. 8th Edition. 2007.

Wolsey, L.A. and Nemhauser, G. L. Integer and Combinatorial Optimization. John Wiley & Sons. 1999.

Interfaces - A Journal of the Institute for Operations Research and Management Science (INFORMS), subscribed by IIT Delhi, available on IITD library website.


## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | CPLEX, MS Excel |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | Videos demonstrating key principles, INFORMS subscription |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | Industry Visits to identify and solve problems |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | PROBABILITY AND STATISTICS |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Core |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | MEL761 |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** Nomesh B. Bolia, Makarand S Kulkarni | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: This course aims to develop a strong base of fundamentals of probability and statistics in students. The concepts and tools learned here are a critical input to all courses and projects of the programme. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Probability Laws, Random Variables, Conditional Probability and Bayes Theorem, Important Random Variables and their properties, Joint Probability Distributions, Law of Total Probability, Law of Large Numbers, Central Limit Theorem, Estimation Theory, Parameter Estimation, Hypothesis Testing using Parametric and Non-Parametric Methods, Goodness of fit tests, ANOVA, Linear Regression (Simple, Generalized) and Logistics Regression. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Probability and Random Variables | 2 |
| 2 | Conditional Probability | 2 |
| 3 | Important Random Variables and their properties | 4 |
| 4 | Joint Probability Distributions | 3 |
| 5 | Law of Total Probability, Law of Large numbers, Central Limit Theorem | 3 |
| 6 | Estimation Theory and Parameter Estimation | 4 |
| 7 | Hypothesis Testing (Parametric, Non Parametric) | 3 |
| 8 | Goodness of Fit Tests | 2 |
| 9 | Design of Experiments | 5 |
| 10 | ANOVA | 5 |
| 11 | Linear Regression | 4 |
| 12 | Logistics Regression | 5 |
| | | |
| | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
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| | | |
| COURSE TOTAL *(14 times 'P')* | | |

**18. Suggested texts and reference materials**

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| Introduction to Probability Models, Sheldon Ross, Academic Press Inc, 10th Edition<br><br>Statistical Inference, G. Casella, R. Berger, Cengage Learning, 2nd Edition<br><br>NIST statistics handbook |

**19. Resources required for the course** *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | Videos demonstrating key principles |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | |

**20. Design content of the course** *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | INTRODUCTION TO STOCHASTIC MODELING AND SIMULATION |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective |
| **7.** | **Pre-requisites** (course no./title) | PG course on Probability and Statistics |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NA |
| 8.3 | Supercedes any existing course* | MEL770 |
| **9.** | **Not allowed for** (indicate program names) | Not allowed for any UG Students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☐ 2nd sem ☒ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** Nomesh B. Bolia, Kiran Seth | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: Many practical situations can be modeled (and consequently) as standard and derived stochastic models. The resulting problems can then be solved either analytically or using simulation if the problem is too complex. The objective of the course thus is to expose students to: 1) creating models for practical problems 2) tools to analyze these models 3) applications of modeling and these tools to real life problems and prepare them for more advanced topics such as Renewal theory and optimal control |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Introduction to Discrete Time Markov Chains - definition and characterization, Transient Distributions, Limiting Behavior, Cost models, First passage times, Applications/Case studies; Poisson Processes,<br>Continuous Time Markov Chains - introduction, Transient and limiting behavior, Cost models, Applications/Case studies; Simulation - basics, discrete event simulation, Monte |

| | |
|---|---|
| | Carlo Simulation |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Quick Review of Probability, Random Variables, Stochastic Processes | 2 |
| 2 | Discrete Time Markov Chains (DTMC) – Introduction, Characterization | 2 |
| 3 | DTMC-transient distributions, limiting behavior | 5 |
| 4 | DTMC-cost models, first passage times | 4 |
| 5 | DTMC-applications, case studies | 1 |
| 6 | Exponential Random Variable, Poisson Processes | 2 |
| 7 | Continuous Time Markov Chains (CTMC) – intro, characterization | 3 |
| 8 | DTMC-transient distributions, limiting behavior | 5 |
| 9 | DTMC-cost models, applications/case studies | 4 |
| 10 | Discrete Event Simulation, Monte Carlo Simulation | 4 |
| 11 | Variance Reduction Techniques | 5 |
| 12 | Applications to queuing, finance etc | 5 |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

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|---|
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## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
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| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| Kulkarni, V.G., Modeling and Analysis of Stochastic Systems (PG level textbook), Second Edition, CRC Press, 2010.<br><br>Fishman, G. S., Monte Carlo: Concepts, Algorithms and Applications, Springer-Verlag, 1996<br><br>Fishman G. S., Discrete Event Simulation: Modeling, Programming and Analysis. Springer-Verlag, 2001 |

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | Anylogic |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | Introductory videos to motivate applications |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD projector and sound |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engineering |
| **2.** | **Course Title** *(< 45 characters)* | LOGISTICS |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3.0 |
| **5.** | **Course number** | |
| **6.** | **Status** (*category* for *program*) | Elective |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NO |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | |
| 8.3 | Supercedes any existing course | |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | UG Students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☒ 2nd sem ☒ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | may be |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: 1 To gain a working understanding of logistics principles and to expose students to the vocabulry & terminology of logistics<br>2. To introduce students to the key activities performed by the logistics function including distribution, transportation, global logistics and inventory control<br>3. To view logistics as a strategic function that creates value and competitive advantage<br>4. To refine applied data analysis skills by analyzing and using supply chain data to make business decisions<br>5. To understand current challenges facing logistics |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Logistics Management is the part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin |

| | |
|---|---|
| | and the point of consumption in order to meet customers' requirements.<br>This course provides a practical, management perspective of the following areas of logistics: distribution, transportation, international logistics, inventory control, sustainable logistics practices, key performance indicators, supply chain finance, leadership in a supply chain role, and an introduction to logistics technology including RFID and ERP systems. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Evolution of Logistics and its role in SCM vis-à-vis in an organization, Logistics and other business functions, Integrated vs frgamented logistics, | 3 |
| 2 | Financial impact of logistics decisions, various fianncial measures for logistics ,Balance sheet and logistics performance, case studies | 3 |
| 3 | Logistics as a strategic aligned function rather than a mere operational ligned , Strategic decisions in logistics - imperatives and implications, forecasting and its implications for strategy, examples of strategic decisions | 4 |
| 4 | Inventory and Logistics trade off Push and Pull supply chians and consequent logistics decisions ,typical inventory models | 4 |
| 5 | Role of customer value and design of a logistics network flows, location etc. , case studies in practice | 3 |
| 6 | Transportation modes, alternatives and deciion making , impact on outbound logistics and their evaluation , case studies | 4 |
| 7 | Information systems and logitics intreface, tradeoff bettween information and transportation issues, , case studies | 3 |
| 8 | IT based solutions-GPS, RFID and web enabled logistics | 4 |
| 9 | Legal and regualtory issues in Logistics, Role of Freght Forwarders, Role of aggregators etc and integration of other functions | 3 |
| 10 | Sustainble logistics and logistics issues, logistics design for reverse flow, role of reverse logistics, green measures | 3 |
| 11 | Performance measurement and evalution of logistics function-various measures both Quntitative vs qualitative measures | 4 |
| 12 | Implementation ssues in logistics-Global trend, Human issues, Role of Technology. Informal or unorganised logistics, case stuudies | 4 |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

NA

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1 Chrostopher Martn. Logistics and Supply Chain management, Fincial times Book Series, 2011
2. Coyle J J , Bardi E J , Manageent of Business Logistics : A Supply Chain Perspective, South-western College Publi., 2002

**19. Resources required for the course** *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | videos on contemporary logistics |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | general class room with LCD projection |
| 19.7 | Site visits | |

**20. Design content of the course** *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | 10% |
| 20.3 | Project-type activity | 30% |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | MAINTENANCE PLANNING |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | SML844(10%), ITL709(30%) |
| 8.3 | Supercedes any existing course* | MEL866 |
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☐ 2nd sem ☒ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M. S. Kulkarni, N. Bolia | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: The objective of the course is to teach concepts required for modeling of maintenance scenarios and optimization of maintenance plans. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Introduction to maintenance management, Reliability basics, Asset criticality Analysis, Reliability centered maintenance, Basic maintenance models for age and time based replacement, block and group replacement, inspection and shock based replacement, imperfect maintenance models, Maintainability models, Availability models, Life cycle cost models, Simulation based approach for maintenance planning, Queuing models for maintenance planning, Models for condition monitoring, Models for Maintenance scheduling, Maintenance performance measurement, Asset management practices, Case studies. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction to maintenance management | 1 |
| 2 | Reliability basics | 5 |
| 3 | Asset criticality analysis | 2 |
| 4 | Reliability centered maintenance | 3 |
| 5 | Basic maintenance models | 10 |
| 6 | Simulation based approach for maintenance planning | 5 |
| 7 | Queuing models for maintenance planning | 5 |
| 8 | Models for condition monitoring | 3 |
| 9 | Models for Maintenance scheduling | 4 |
| 10 | Maintenance performance measurement | 1 |
| 11 | Asset management practices | 3 |
| | | |
| | | |
| | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| | | |
| | | |
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| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.


Patrick O'Connor, A. Kleyner, Practical Reliability Engineering, Wiley India,5th Ed., 2012.
C. E. Ebeling, Reliability and maintainability engineering, Tata McGraw Hill, 2nd Ed., 2009.
I. Gertsbakh, Reliability Theory: With applications to preventive maintenance, Springer, 2005.
A. K.S. Jardine, A. H.C. Tsang, Maintenance, Replacement, and Reliability: Theory and Applications, CRC Press, 1st Ed., 2005.
A. C. Marquez, The Maintenance Management Framework: Models and Methods for Complex Systems Maintenance, Springer Verlag, 1st Ed., 2007.


## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | Matlab, R, Reliasoft |
| 19.2 | Hardware | PC, Laptop |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | 100% |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engineering |
| **2.** | **Course Title** *(< 45 characters)* | MANUFACTURING INFORMATICS |
| **3.** | **L-T-P structure** | 3-1-0 |
| **4.** | **Credits** | 4 |
| **5.** | **Course number** | |
| **6.** | **Status** (*category* for *program*) | Elective for PG but open to UG as a DE |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | Pre-requisite for UG: manufacturing system design |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | None |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | None |
| 8.3 | Supercedes any existing course | |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐Every sem ☐1st sem ☐2nd sem ☒Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M S Kulkarni, S G Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)***:** The objective of this course is to introduce students to Manufacturing Analytics as an approach to deal with the challenge of optimal decision making in manufacturing organizations. |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)***:** Introduction to manufacturing analytics (manufacturing analytics concepts, contemporary issues in high-value manufacturing, and opportunities provided by analytics and big data technologies), data types and applications (point of sale data, service touch point data, service centre data, warranty data, machine condition data, machine failure history, machine utilisation data, work in process data and online quality control data), optimisation of manufacturing processes (optimisation concepts, evolutionary computing, multi-objective optimisation, and applications of optimisation for sequential and assembly processes), and latest advancements in manufacturing analytics (virtual reality, augmented reality, and motion capture gaming technologies for |

| | |
|---|---|
| | manufacturing). |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Manufacturing analytics concepts | 2 |
| 2 | Contemporary issues in high-value manufacturing | 2 |
| 3 | Opportunities provided by analytics and big data technologies | 2 |
| 4 | Point of sale data, service touch point data, service centre data and warranty data | 4 |
| 5 | Machine condition data, machine failure history and machine utilisation data | 4 |
| 6 | Work in process data and online quality control data | 4 |
| 7 | Optimisation concepts, evolutionary optimization, multi-objective optimization | 12 |
| 8 | Applications of optimisation for sequential and assembly processes | 6 |
| 9 | Virtual reality for manufacturing | 2 |
| 10 | Augmented reality for manufacturing | 2 |
| 11 | Motion capture gaming technologies for manufacturing | 2 |
| 12 | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

NA

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | Case studies on data types and applications | 7 |
| 2 | Hands-on optimisation exercises | 7 |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| COURSE TOTAL *(14 times 'P')* | | 14 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Deb, K. (2001). Multi-objective optimization using evolutionary algorithms, Wiley, London.

Tiwari, M.K. and Harding, J.A. (2011). Evolutionary computing in advanced manufacturing, Wiley, London, UK.

Handbook of Manufacturing Control by H. Lodding, Springer 2013.

| |
|---|
| |

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | 30% |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engineering |
| **2.** | **Course Title** *(< 45 characters)* | PROJECT MANAGEMENT |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective for PG and open to UG as DE |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | 30% with SML 845 |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | 10% with ESL 795 |
| 8.3 | Supercedes any existing course | None |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐Every sem ☐1st sem ☐2nd sem ☒Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M. S. Kulkarni, Prof. S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | May be |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)***:** The obective of this course is to provide an introduction to Project management by focusing on the major decisions in the life cycle of a project. It would focus on the stages of Project conception, project appraisal, project planning using network models, implementation and completion.It would emphasize the interdisciplinary nature of projects and the importance of leadership and teamwork. |

| | |
|---|---|
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)***:** The nature of projects, the project as a non-repetitive unit production system, the project as an agent of change. Project Identification considering objectives and SWOT analysis, Screening of Project Ideas, Technical, Market, Financial,Socio-economic and Ecological Appraisal of a project. Wpork break down |

| | |
|---|---|
| | structure and network development. Basic Scheduling, Critical Path and four kinds of floats. , Scheduling under probabilistic durations, Time Cost tradeoffs, Project Monitoring with PERT/Cost, Organizational aspects, Computer packages and Project Completion. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Features of projects, Projects as agents of change, Project Life Cycle | 2 |
| 2 | Project Identification,.Screening of Project Ideas | 3 |
| 3 | Project Appraisal- Technical, Market, Financial, Socio-economic & Ecological | 4 |
| 4 | Multi-criteria evaluation of project Proposals. | 3 |
| 5 | Work breakdown structure and Network Development.<br>A-O-A and A-O-N networks, role of dummies. | 3 |
| 6 | Basic Deterministic Scheduling with CPM.<br>Probabilistic Scheduling with PERT.<br>Analysis of PERT errors. Use of PNET and CCP. | 4 |
| 7 | Project Simulation for estimation of mean, variance and criticality indices. Precision and confidence levels in simulation. | 4 |
| 8 | Project Crashing- heuristic and exact procedures. | 4 |
| 9 | Resource aggregation, leveling and allocation in projects. | 4 |
| 10 | Project monitoring & Control with PERT/Cost. | 2 |
| 11 | Precedence Diagramming, Decision CPP and stochastic networks (GERT) | 2 |
| 12 | Organizational and behavioural issues in Projects<br>13. Computer packages and IT for effective project coordination | 4<br>3 |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.


Jack R. Meredith (Author), Samuel J. Mantel Jr., Project Management: A Managerial Approach, Wiley; 8 edition, 2011.

A Guide to the Project Management Body of Knowledge: PMBOK(R) Guide, Project Management Institute, 5 edition, 2013.

Harold R. Kerzner, Project Management: A Systems Approach to Planning, Scheduling, and Controlling, Wiley; 11 edition, 2013.
Chandra, P, Projects: Preparation, Appraisal Budgeting and Implementation (5th Ed) Tata McGraw Hill, N.Delhi, 2002.
Nicholas, John M., Herman Steyn, Project Management for Business and Technology: Principles and Practice, Routledge; 4 edition, 2012.

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | 10% |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | QUALITY SYSTEMS |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | SML715 (10%), SML816 (30%) |
| 8.3 | Supercedes any existing course* | MEL752, MEL876, MEL768 |
| **9.** | **Not allowed for** (indicate program names) | UG students |
| **10.** | **Frequency of offering** | ☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem |
| **11.** | **Faculty who will teach the course** M. S. Kulkarni, Prof. S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | No |
| **13.** | **Course objective** *(about 50 words)*: The objective of the course is teach students the concepts required for designing and implementing a quality system in a manufacturing or a service organization. | |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Introduction to quality systems through approaches proposed by Juran, Deming, Baldridge, Taguchi, Crossby etc., Quality costs, Requirements analysis using methods like Kano's analysis, Requirement mapping using QFD, Product and process analysis using Design and Process FMEA, Robust design and process improvement using online and offline methods for design and analysis of experiments, Shainin's tools for variability reduction, Process capability analysis and loss functions, Statistical tolerancing, Design of control charts and acceptance sampling plans, Quality | |

| | |
|---|---|
| | standards like IS0 9000, ISO 14000, CMMI etc.; Service quality models and Service blueprints and Service FMEA, Case studies. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction to quality systems | 2 |
| 2 | Quality costs | 1 |
| 3 | Requirements analysis | 1 |
| 4 | Requirement mapping using QFD | 2 |
| 5 | Product and process evaluation using Design and Process FMEA | 2 |
| 6 | Robust design and process improvement using design and analysis of experiments | 8 |
| 7 | Shainin's tools for variability reduction | 3 |
| 8 | Process capability analysis and loss functions | 3 |
| 9 | Statistical tolerancing | 1 |
| 10 | Design of control charts | 6 |
| 11 | Design of acceptance sampling plans | 5 |
| 12 | Quality standards | 4 |
| 13 | Service quality models, Service blueprints, Service FMEA | 4 |
| | | |
| | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| | | |
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| | | |
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| | | |
| COURSE TOTAL *(14 times 'P')* | | 28 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.


A. Mitra, Fundamentals of Quality Control and Improvement, 3rd Edition, Wiley India, 2013
The Certified Quality Engineer Handbook, 3rd Edition, ASQ, 2010
D. C. Montgomery, DESIGN AND ANALYSIS OF EXPERIMENTS, 8TH ED, Wiley India, 2013.
K. Bhote, World Class Quality: Using Design of Experiments to Make It Happen, AMACOM; 2nd Ed, 2000.
S. S. Steiner, R. J. Mackay, Statistical Engineering: An Algorithm for Reducing Variation in Manufacturing Processes, ASQ, 2005.
E.L.Grant & R.S. Leavenworth, Statistical Quality Control, McGraw Hill, NY, 2012.
J.M. Juran and F.M. Gryna, Quality Planning and Analysis, Tata McGraw Hill.
D. C. Montgomery Introduction to SQC, , John Wiley & Sons, 2002
CMMI-SVC, Version 1.3 manual, SEI-CMU, 2010.


## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | Matlab, R |
| 19.2 | Hardware | PC, Laptop |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | 20% |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | RELIABILITY ENGINEERING |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective |
| **7.** | **Pre-requisites** (course no./title) | None |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | NA |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | AML730(10%), AML871(10%), SML844 (10%) |
| 8.3 | Supercedes any existing course* | NA |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | UG students |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M. S. Kulkarni, N. Bolia | |
| **12.** | **Will the course require any visiting faculty?** | No |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: The objective of the course is teach students the concepts required for designing reliable systems, reliability test plan design, failure data analysis and reliability prediction. |

| | |
|---|---|
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Time to failure distributions; Parameter estimation for non-repairable systems; Reliability models for series, parallel and mixed configurations; Reliability models for active/passive redundancy, load sharing systems, mixed population, competing failure modes; Stress-Strength models; Conditional reliability models and residual life calculation; Reliability models for multiple operational phases; Shock based reliability models; Reliability models for non-repairable systems; Parameter estimation for |

| | |
|---|---|
| | repairable systems, Failure Mode and Effects Analysis, Fault Tree Analysis; Failure simulation; Warranty cost analysis; Reliability allocation; Reliability of production systems; Test plan design for non-accelerated life tests; Accelerated life testing models; Burn-in test plans. |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction to reliability engineering | 1 |
| 2 | Non parametric methods for reliability estimation | 1 |
| 3 | Time to failure distributions | 2 |
| 4 | Parameter estimation for non-repairable systems | 3 |
| 5 | Reliability and hazard rate models for single and mixed population, competing failure modes | 2 |
| 6 | Reliability models for series, parallel, mixed configurations, 'k-out-of-n' configuration, passive redundancy, load sharing systems | 3 |
| 7 | Stress-Strength models, Shock based reliability models, Conditional reliability models and residual life calculation, Reliability models for multiple operational phases | 4 |
| 8 | Reliability models for non-repairable systems based on homogeneous and non-homogeneous Poisson process and generalized renewal process. | 3 |
| 9 | Parameter estimation for repairable systems | 4 |
| 10 | Failure Mode and Effect Analysis, Fault Tree Analysis | 3 |
| 11 | Failure simulation | 3 |
| 12 | Warranty cost analysis | 3 |
| 13 | Reliability allocation methods | 2 |
| 14 | Reliability of production systems | 2 |
| 15 | Test plan design for non-accelerated life tests; Accelerated life testing models; Burn-in test plans | 5 |
| | | |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'P')* | | 28 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

| |
|---|
| Patrick O'Connor, A. Kleyner, Practical Reliability Engineering, Wiley India,5th Ed., 2012<br>C. E. Ebeling, Reliability and maintainability engineering, Tata McGraw Hill, 2nd Ed., 2009 |

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | Matlab, R |
| 19.2 | Hardware | PC, Laptop |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD Projector |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | 20% |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engineering |
| **2.** | **Course Title** *(< 45 characters)* | SERVICE SYSTEM DESIGN |
| **3.** | **L-T-P structure** | 2-0-2 |
| **4.** | **Credits** | 3.0 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | PG Elective open to UG as DE |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | None |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | None |
| 8.3 | Supercedes any existing course | None |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | students other than those from Mech Engg, IDDC and ITMMEC |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐Every sem ☐1st sem ☐2nd sem ☒Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** M S Kulkarni, P V M Rao | |
| **12.** | **Will the course require any visiting faculty?** | may be |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)*: To introduce students to scientific approaches for service and product-service-system (PSS) design |
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)*: Need for servitization, Service system types, Key dimensions of service systems, Frameworks for service system design, tools for service system design, Value co-creation, Service quality models, Economics of service systems, Service contract design, CMMI-SVC model for service systems, Case studies on service system design |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction to course and Need for servitization | 1 |
| 2 | Service system types including pure service, product oriented, use oriented and result oriented systems. | 1 |
| 3 | Key dimensions of service systems eg.,customer, people, information and technology | 1 |
| 4 | Frameworks for service and product-service-system design | 3 |
| 5 | Tools for service system design | 7 |
| 6 | Value co-creation through various co-creation platforms | 3 |
| 7 | Service quality models | 3 |
| 8 | Economics of service systems | 3 |
| 9 | Contract design for services and produc-service-systems | 1 |
| 10 | CMMI-SVC model for service systems | 2 |
| 11 | Case studies | 3 |
| 12 | | |
| COURSE TOTAL *(14 times 'L')* | | 28 |

## 16. Brief description of tutorial activities

NA

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | Identifying service and value co-creation opportunities | 4 |
| 2 | Capturing and prioritizing service requirements | 4 |
| 3 | Identifying service mechanisms and channels | 4 |
| 4 | Development of service blue prints | 4 |
| 5 | Service failure analysis | 4 |
| 6 | Service quality model | 4 |
| 7 | Project presentation | 4 |
| 8 | | |
| 9 | | |
| 10 | | |
| COURSE TOTAL *(14 times 'P')* | | 28 |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Made to Serve, by T. baines and H. Lightfoot, Wiley 2013.

Introduction to Product/Service-System Design, S. Tomohiko, L. Mattias, Springer, 2010.

The science of service systems, by H. Demirkan, J. C. Spohrer ands V. Krishna, Springer, 2011.

Servive systems implementation, by H. Demirkan, J. C. Spohrer ands V. Krishna, Springer, 2011.

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | video clips |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | LCD projector |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | |
| 20.3 | Project-type activity | 50% |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engineering |
| **2.** | **Course Title** *(< 45 characters)* | SUPPLY CHAIN MANAGEMENT |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3.0 |
| **5.** | **Course number** | NA |
| **6.** | **Status** (*category* for *program*) | Elective |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | |
| 8.3 | Supercedes any existing course | MEL756 |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | Students who have done SCM course |

| | | |
|---|---|---|
| **10.** | **Frequency of offering** | ☐Every sem ☐1st sem ☐2nd sem ☒Either sem |

| | | |
|---|---|---|
| **11.** | **Faculty who will teach the course** S. G. Deshmukh | |
| **12.** | **Will the course require any visiting faculty?** | may be |

| | |
|---|---|
| **13.** | **Course objective** *(about 50 words)***:**<br>1. Develop an understanding of the Supply Chain Management and basic flows in SCM viz Material, Money and Information flows<br>2. Develop comptency in handling various analytical tools of SCM<br>3.Foster appreciation of managing and evaluating e a complex supply chain in a holistic manner<br>4. Understand the managerial implications in implementing supply chain solutions vis-à-vis developing appreciation for global SC and customet focus |

| | |
|---|---|
| **14.** | **Course contents** *(about 100 words) (Include laboratory/design activities)***:**<br>Supply Chain Orienetation and Management, Various flows in a typical supply chain, Supply chain strategy ,Customer focus, Location Decisions ,Strategic alliance issues , Inventory Decisions, Information Decicions – Bull whip effect and its ramifications, remedies , Transportation Decicions - Supply chain modeling (both quantitative and qualitative) and analysis , Performance |

| | |
|---|---|
| | measurement; Various evaluation frameworks , Risk and supply chain vulnerabilities, Reverse Logistics and decision making involved , Supply chain i implementation vis-à-vis global issues involved, e-commerce and contemporary models of bsuiness |

## 15. Lecture Outline *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Evolution of supply chain- classical materials management, distribution logistics to supply chain, Push & Pull orientation, imperatives and drivers for SCM | 1 |
| 2 | Typical flows- Material, Money and Information in a SC , Taxonomy for various SCs | 2 |
| 3 | Strategic and Locational decisions in SC - imperatives and implications, forecasting and its implications for strategy, examples of strategic decisions , Factors for locational decisions , examples of infrsatcture based decisinns for location, IT based SC s (such as Amazon.com, snapdeal etc.), Strategic alliances and their impacts | 4 |
| 4 | Inventory: Types and variety , importance of inventory and cost factors involved and their implications, Stochastic models for inventory , multi-echelon decisions, | 4 |
| 5 | Determinants of risk and various strateegies for risk evaluation, utility based frmeworks for risk assessment | 2 |
| 6 | Transportation decisions - various alternatives and impact on outbound logistics and their evaluation , case studies | 2 |
| 7 | Role of information vis-à-vis inventory,Distortion effetct- Bull whip effect: causes and remedies, IT based solutions, Case studies , e-commerce and its linkages with Information flows and money flows, contemporary practces | 4 |
| 8 | modelling in supply chain- Network models, supplier evaluation models, multi-criteria based models, Game theoretic models, Frameworks such as fuzzy logic and other soft computing based templates such as GA, ANN etc. | 6 |
| 9 | Customer issues , Value for money, Role and dsign and architecture of information systems from enhancing customer value ( ERP, Web enabled initiatives in SC) case studies | 3 |
| 10 | Reverse supply chain, green and environmentally responsive chains, Humanitarian Supply Chain, Disaster Management in Supply chains, Design for disposal | 4 |
| 11 | Performance measurement frameworks in SC- Functional measures, Balanced score card, SCOR and other templates, measures for green supply chains, Quntitative vs qualitative measures | 5 |
| 12 | Implementation ssues in SC-Sooft issues vs hard issues, Group nmotivation, team work in a high performance supply chains, Role of IT vis-à-vis Human based systems ,Globa orientation and global issues in SCM, Contemporary practices in SCM , Governnace issues in SCM | 5 |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| Module no. | Experiment description | No. of hours |
|---|---|---|
| 1 | | |
| 2 | | |

| | | |
|---|---|---|
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1 Sharma S, Supply Chain Manageent, Oxford University Press, 2010
2. Chopra, S. and P. Meindl ,Supply Chain Management: Strategy, Planning and Operation. 5th Edition, Prentice-Hall., 2013
3 David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi, and Ravi Shankar. ,Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies.3rd Edition, Mc-Graw Hill, 2008

## 19. Resources required for the course *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | MS-excel |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | videos from youtube /NPTEL |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | general class room with LCD projection |
| 19.7 | Site visits | |

## 20. Design content of the course *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | 20% |
| 20.3 | Project-type activity | 40% |
| 20.4 | Open-ended laboratory work | |
| 20.5 | Others (please specify) | |

Date: (Signature of the Head of the Department)

# COURSE TEMPLATE

| | | |
|---|---|---|
| **1.** | **Department/Centre proposing the course** | Mechanical Engg |
| **2.** | **Course Title** *(< 45 characters)* | VALUE ENGINEERING AND LIFE CYCLE COSTING |
| **3.** | **L-T-P structure** | 3-0-0 |
| **4.** | **Credits** | 3 |
| **5.** | **Course number** | - |
| **6.** | **Status** (*category* for *program*) | Elective |

| | | |
|---|---|---|
| **7.** | **Pre-requisites** (course no./title) | nil |

| | | |
|---|---|---|
| **8.** | **Status vis-à-vis other courses** *(give course number/title)* | |
| 8.1 | Overlap with any UG/PG course of the Dept./Centre | Value Engg, UG |
| 8.2 | Overlap with any UG/PG course of other Dept./Centre | NO |
| 8.3 | Supercedes any existing course* | MEL671 |

| | | |
|---|---|---|
| **9.** | **Not allowed for** (indicate program names) | UG Students |
| **10.** | **Frequency of offering** | ☐ Every sem ☐ 1st sem ☐ 2nd sem ☐ Either sem |
| **11.** | **Faculty who will teach the course : S. G. Deshmukh, A D GUPTA** | |
| **12.** | **Will the course require any visiting faculty?** | NO |

**13. Course objective** *(about 50 words)*:

The broad objectives of the course are to teach the students the concepts of Value Engineering/Value Analysis and Life Cycle Costing. They should be able to apply Value Engineering Job Plan and other techniques of value improvement to various practical situations and projects.

**14. Course contents** *(about 100 words) (Include laboratory/design activities)*:

| | |
|---|---|
| | Introduction to Value Engineering and Value Analysis, Methodology of V.E., Quantitative definition of use value and prestige value, Estimation of product quality/performance, Classification of Functions, Functional Cost and Functional Worth, Effect of value improvement on profitability. Introduction to V.E. Job plan / Functional Approach to Value Improvement, Various phases and techniques of the job plan.<br>Life Cycle Costing for managing the Total Value of a Product, Cash flow diagrams, Concepts in LCC, Present Value concept, Annuity cost concept, Net Present Value, Pay Back period, Internal rate of return on investment (IRR), Continuous discounting, Examples and illustrations.<br>Creative thinking and creative judgment, False savings, System Reliability, Evaluation Matrix, Assessment of value alternatives, Estimation of weights and efficiencies, Sensitivity analysis, Utility transformation functions, Fast diagramming, Critical path of functions, DARSIRI method of value analysis. Critical review of some industry oriented projects and case studies. |

**15. Lecture Outline** *(with topics and number of lectures)*

| Module no. | Topic | No. of hours |
|---|---|---|
| 1 | Introduction to Value Engineering and Value Analysis, Methodology of V.E., Difference from conventional methods of cost reduction, Unnecessary costs, Quantitative definition of use value and prestige value, Estimation of product performance. | 4 |
| 2 | Classification of Functions, Relationship between use functions and esteem functions in product design, Functional Cost and Functional Worth, Effect of value improvement on profitability of an organization | 4 |
| 3 | Introduction to V.E. Job plan / Functional Approach to value improvement, Various phases and techniques of the job plan, Factors governing project selection. | 3 |
| 4 | Life Cycle Costing for managing the Total Value of a product, Cash flow diagrams, Concepts in LCC, Present Value concept, Annuity cost concept, Net Present Value, Pay Back period, Internal rate of return on investment (IRR), Continuous discounting; Judicious examples, problems and illustrations. | 10 |
| 5 | General Phase, Information Phase, Cost structure of a product, Cost allocation to various specifications and requirements, Function Phase, Numerical evaluation of functional relationships, Checks of consistency, Function-cost-weight matrix, VIP index. | 4 |

| | | |
|---|---|---|
| 6 | Creativity Phase, Brain storming, Evaluation Phase, Creative judgment; False savings, Savings and probability of success, Functional Development Worksheet, Investigation Phase, Development of workable and saleable solutions. | 4 |
| 7 | Recommendation phase, Determination of cut-off point (COP), Road blocks in implementation. Scheduling implementation of a VA project, Network planning, Implementation program. | 3 |
| 8 | Decision matrix, Evaluation of value alternatives, Estimation of weights and efficiencies, Quantitative and Qualitative Utility transformation functions, Sensitivity analysis, Examples. | 3 |
| 9 | Fast diagramming, Ground rules for Fast diagram, Critical path of functions; Supporting and all-time functions, DARSIRI method of value analysis, Purchase price analysis. | 3 |
| 10 | Discussion and critical analysis of some industry oriented projects and case studies | 4 |
| COURSE TOTAL *(14 times 'L')* | | 42 |

## 16. Brief description of tutorial activities

| |
|---|
| NA |

## 17. Brief description of laboratory activities

| | **Experiment description** | **No. of hours** |
|---|---|---|
| NA | | |
| | | |
| | | |
| COURSE TOTAL *(14 times 'P')* | | |

## 18. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.


1. S. S. IYER, Value Engineering - A How to do Manual, New Age International Publishers, New Delhi.
2. Arthur E. Mudge, Value Engineering – A Systematic Approach, Mc Graw Hill Book Co., New York.
3. A. D. Raven, Profit Improvement through Value Analysis, Value Engineering and Purchase Price Analysis, Cassell and Co., London.

4. L. D. Miles, Techniques of Value Analysis and Engineering, Mc Graw Hill Book Co., New York.
5. M. S. Vittal, Value Engineering for Cost Reduction and Product Improvement, Syscons Publication, Bangalore.
6. ASTME-American Society for Tool and Manufacturing Engineers, Value Engineering in Manufacturing, Prentice Hall.
7. S.N. Chary, Production & Operations Management, Tata Mc . Graw Hill, New Delhi.
8. Prasanna Chandra, Projects Preparation, Appraisal, Budgeting and Implementation, Tata Mc. Graw Hill, New Delhi.
9. Various Journals in Industrial Engineering / Value Engineering / Productivity
10. http://www.value-eng.org
11. http://www.value-engineering.com

**19. Resources required for the course** *(itemized & student access requirements, if any)*

| | | |
|---|---|---|
| 19.1 | Software | |
| 19.2 | Hardware | |
| 19.3 | Teaching aides (videos, etc.) | |
| 19.4 | Laboratory | |
| 19.5 | Equipment | |
| 19.6 | Classroom infrastructure | As needed |
| 19.7 | Site visits | |

**20. Design content of the course** *(Percent of student time with examples, if possible)*

| | | |
|---|---|---|
| 20.1 | Design-type problems | |
| 20.2 | Open-ended problems | -- |
| 20.3 | Project-type activity | -- |
| 20.4 | Open-ended laboratory work | -- |
| 20.5 | Others (tools and techniques) | -- |

Date: (Signature of the Head of the Department)