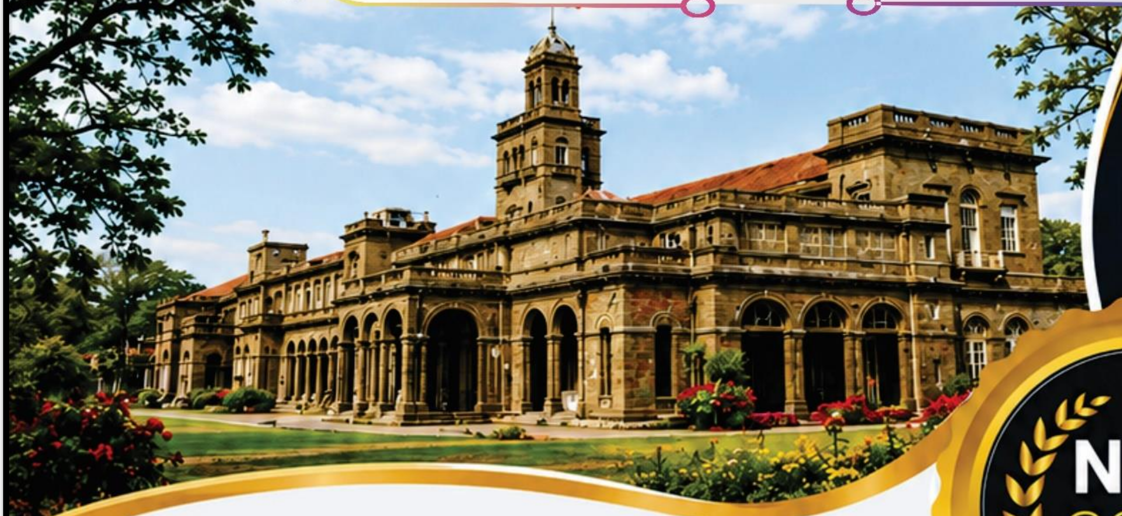
Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

Board of Studies (BoS)
Mechanical and Automobile Engineering



NEP 2020

VALUE

VALUE STREAM

FLOW

PULL

PERFECTION

Honors Program in
Lean Manufacturing

(18 Credits)

2024 PATTERN

(w.e.f Academic Year: 2026-27)

Website: https://www.unipune.ac.in/

Contents

Semester: V, VI, VII & VIII Courses (Lean Manufacturing)

NOMENCLATURE

AEC	Ability Enhancement Courses
AICTE	All India Council for Technical Education
CO	Course Outcome
CEP	Community Engagement Project
CCE	Comprehensive Continuous Evaluation
HSSM	Humanities, Social Science, and Management
MDM	Multidisciplinary Minor
MEC	Mechanical Engineering
MOOC	Massive Open Online Course
NPTEL	National Programme on Technology Enhanced Learning
NEP	National Education Policy
PCC	Program Core Course
PEO	Program Educational Objectives
PSO	Program Specific Objectives
SWAYAM	Study Webs of Active-learning for Young Aspiring Minds
UGC	University Grants Commission
VEC	Value Education Course
VSE	Vocational and Skill Enhancement Course
WK	Knowledge and Attitude Profile

PREFACE BY BOARD OF STUDIES

Dear Students and Teachers,

We, the members of the Board of Studies – Mechanical Engineering, are very happy to present the Third-Year Mechanical Engineering syllabus, effective from the **Academic Year 2026–27 (2024 Pattern).** We are confident that you will find this syllabus both interesting and challenging. The present curriculum will be implemented for Third Year Engineering from the academic year 2026–27, and it will be subsequently extended to the Final Years in the academic years **2027–28**.

Mechanical Engineering is one of the most sought-after branches among engineering students, which necessitates continuous revision and up gradation of the syllabus. Mechanical Engineering is a dynamic discipline that integrates principles from core engineering fields and supports innovation across manufacturing, design, energy, materials, and automation. This curriculum is designed to provide students with a comprehensive understanding of the fundamentals, emerging technologies, and practical applications in Mechanical Engineering, while also equipping them to meet the demands of a rapidly evolving industry.

The revised syllabus aligns with the vision of **NEP-2020**, and conforms to the frameworks set by Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies. It takes into account recent technological developments, innovations, and industry needs to ensure students are well- prepared for professional challenges.

Wherever applicable, additional learning resources such as NPTEL and SWAYAM links are provided at the end of each course. Students are encouraged to utilize these platforms for self-learning, engage in online courses, and undertake additional projects to enhance their knowledge and skill set. On successful completion, they are advised to submit their course certifications, which will further support and enrich their academic growth.

This curriculum is the result of collaborative efforts involving academic experts, industry professionals, and alumni to ensure relevance and excellence. It is designed not only to meet current industry expectations but also to prepare students for higher studies, research, and entrepreneurial ventures in the field of Mechanical Engineering.

We hope this curriculum inspires students to become technically competent professionals, responsible citizens, and contributors to the technological and sustainable advancement of society.

Dr. Pradeep A. Patil
Chairman

PROGRAM SPECIFIC OUTCOMES

PSO1 : **SPECIFY, DESIGN** and **EVALUATE** mechanical components and systems using modelling and analysis software.

PSO2 : **APPLY** knowledge of machines, tools, automation, properties of advanced materials and modern management methods for manufacturing of mechanical components and systems.

PSO3 : **APPLY** core aspects of thermal and fluid engineering to determine the performance of mechanical systems including power absorbing and power generating systems.

PROGRAM EDUCATIONAL OBJECTIVES

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing a graduate to achieve.

PEO1 : The graduate will have a successful career in mechanical engineering with strong technical, research & professional skills.

PEO2 : The graduate will possess an ability to work in diversified fields along with team work and leadership qualities.

PEO3 : The graduate will continue to learn and to adapt in a society of constantly evolving technological environment

PROGRAM OUTCOMES

Program Outcomes (POs) are statements that articulate what students are expected to know, understand, and be able to do by the time they graduate from the program. These outcomes are aligned with the overall educational objectives of the program and reflect the skills, knowledge, attitudes, and behaviors acquired by students throughout their academic journey. On successful completion of B.E. in Mechanical Engineering, graduating students/graduates will be able to:

PO No.	Title	Program Outcome Description
PO1	Engineering Knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
PO2	Problem Analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3	Design / Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society and environment. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual and Collaborative Team Work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for, and have the preparation and ability for: (i) independent and life-long learning, (ii) adaptability to new and emerging technologies, and (iii) critical thinking in the broadest context of technological change. (WK8)

KNOWLEDGE AND ATTITUDE PROFILE (WK)

WK No.	Focus Area	Description
WK1	Natural Sciences and Social Sciences	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Mathematics and Data Analysis	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	Engineering Fundamentals	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering Specialist Knowledge	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Engineering Design and Environmental Considerations	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Engineering Practice (Technology)	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Role of Engineering in Society	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Research and Critical Thinking	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics and Inclusive Behavior	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability, etc., with mutual respect.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPC V4.0) - (August 2024) Page 55-56

GENERAL RULES AND GUIDELINES

Term	Definition
Course Outcomes (COs)	Course Outcomes are narrower statements that describe what students are expected to know and be able to do at the end of each course. These relate to the skills, knowledge, and behavior that students acquire throughout the course.
Assessment	Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of **Program Educational Objectives (PEOs)** and **Program Outcomes (POs)**.
Evaluation	Evaluation is one or more processes, performed by the **Evaluation Team**, to interpret the data and evidence gathered through assessment practices. It determines how well PEOs or POs are being achieved, and informs decisions for improvement.

ASSESSMENT AND EVALUATION:

Assessment and Evaluation shall be conducted in two parts:
1. Comprehensive Continuous Evaluation (CCE)
2. End-Semester Examination (ESE)

Component	Description	Marks
Comprehensive Continuous Evaluation (CCE)	Conducted at institute level, covering all Units of the syllabus. The design and mark allocation follow the Continuous Assessment Sheet structure.	30
End-Semester Examination (ESE)	Conducted at university level, typically covering the entire syllabus through summative examination.	70
	Total Marks per Subject	**100**

A) <u>Comprehensive Continuous Evaluation (CCE) :</u>

CCE to be conducted either on the basis of Mode 1 or Mode 2.

CCE MODE 1:

To design a Comprehensive Continuous Evaluation (CCE) scheme for a theory subject of 15 or 30 marks with the specified parameters, the allocation of marks and the structure can be as per continuous assessment sheet;

Savitribai Phule Pune University																						
Board of Studies (Mechanical and Automobile Engineering)																						
Comprehensive Continous Evaluation (CCE) [30 Marks Distribution]																						
Class: TE- Mechanical Engineering															Subject: Refrigeration and Air Conditioning							
Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Cumulative Sum				30 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Internal Test	Attendance	Field Activity	Quiz	Internal Test	Attendance	
			A	B	C	D	E	F	G	H	I	J	SUM(A+C+E+G+I)	SUM(B+D+F+H+J)			P	Q	R	S	SUM(P:S)
			10	10	10	10	10	10	10	10	10	10	50	50	100	100	15	5	5	5	30
T9028246474	2020	MAAN PANCHAL	8	8	8	8	8	8	8	8	8	8	40	40	60	75	12	4	3	3.8	22.75

Figure 1 Template Comprehensive Continuous Evaluation (CCE) ***Click*** *here to download* .**Field Activities / Home Assignments**

Field activities and home assignments are essential components of experiential learning. Under this head, course projects, industrial visits, and guest lectures are to be incorporated. For each unit, one such activity should be designed and executed to reinforce theoretical learning through practical exposure.

1. **Course Projects**

   Course Projects should be framed based on real-world problems relevant to the subject. Each course project must be communicated through one of the following modes. It is recommended to complete all the communication modes across different course projects:

- **Poster Presentation**
- **PowerPoint Presentation**
- **Model Making**
- **Field or Survey Report with Oral Presentation** (e.g., case study)
- **Submission of Digital Content (e.g. Video Summary)**

To evaluate these field activities, **assessment rubrics** should be designed. The rubrics should include criteria such as clarity, innovation, subject relevance, presentation skills, and technical content.

Note: Part of work of any co-curricular activities (relevant to subject contents) like national level project competitions, club activities, paper presentations, startup activities can be accepted as a course projects.

2. **Industrial Visit**

   An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the respective field. The purpose is to provide students exposure to actual engineering practices and systems.

Assessment of industrial visits should be carried out using any of the following tools:

- Quiz (based on the visit)

- Interactive video or oral discussion
- Submission of a detailed visit report

3. **Guest Lectures**

Guest lectures should be relevant to the course and highlight advanced topics or recent trends in the field. Subject experts from academia or industry may be invited.

Assessment methods for guest lectures may include:

- Quiz conducted post-lecture
- Attendance monitoring
- Evaluation of attentiveness and participation

Rubrics can be developed, if possible, to objectively assess student involvement in guest lectures.

4. **Quiz**

Unit-wise quizzes should be planned and can be conducted either **online** (Via LMS, Google Forms) or **offline**. Each quiz should include a **pool of 20 questions**, from which **students are required to attempt any 10**.

The quizzes should be diversified across the following question types:

- Simple Multiple Choice Questions (MCQs)
- Numerical MCQs
- Image-based Questions
- Match the Following
- Fill in the Blanks
- Drag and Drop (using images or words)

This variety ensures the assessment caters to different cognitive skills and learning styles.

5. **Internal Tests**

Two major internal tests should be conducted as follows:

1. **Midterm Examination**: This should cover **Unit I and Unit II**, and should include questions targeting

   Bloom's Taxonomy Levels 2, 3, and 4 (UNDERSTAND, APPLY, and ANALYZE).
2. **End term Examination**: This should cover the **remaining units** and should also include questions mapped to **BL Levels 2, 3, and 4**.

CCE MODE 2:

Comprehensive Continuous Evaluation scheme in this mode for a theory subject of **30 marks** with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	12 Marks	Unit 1 & Unit 2 (6 Marks/Unit)
2	Assignments/Case Study	12 Marks	Unit 3 & Unit 4 (6 Marks/Unit)
3	Seminar Presentation/ Open Book Test/ Quiz	06 Marks	Unit 5

- **Unit Test–**

  Format: Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels (Remember, Understand, Apply, Analyze, Evaluate, and Create).

  Implementation: Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.

- **Sample Question Distribution**–
  1. Remembering (2 Marks): Define key terms related to [Topic from Units 1 and 2].
  2. Understanding (2 Marks): Explain the principle of [Concept] in [Context].
  3. Applying (2 Marks): Demonstrate how [Concept] can be used in [Scenario]
  4. Analyzing (3 Marks): Compare & contrast [Two related concepts] from Units 1 and 2
  5. Evaluating (3 Marks): Evaluate the effectiveness of [Theory/Model] in [Situation].

- **Assignments / Case Study:** Students should submit one assignment or one Case Study Report based on Unit 3 and one assignment or one Case Study Report based on Unit 4.

  – ***Format***: Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.

  – ***Implementation:*** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.

- **Seminar Presentation: –**

  Format: Oral presentation on a topic from Unit 5, followed by a Q&A session.

  Deliverables: Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation

  Implementation: Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.

- **Open Book Test: –**

  Format: Analytical and application-based questions to assess depth of understanding. – **Implementation**: Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5

- **Quiz:** –

Format: Quizzes can help your students practice existing knowledge while stimulating interest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.

Implementation**:** Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc

- **Example Timeline for conducting CCE: –**
  1. Weeks 1-4 : Cover Units 1 and 2
  2. Week 5 : Conduct Unit Test (12 marks)
  3. Weeks 6-8 : Cover Units 3 and 4
  4. Week 9 : Distribute and collect Assignments / Case Study (12 marks)
  5. Weeks 10-12 : Cover Unit 5
  6. Week 13 : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- **Evaluation and Feedback: –**
  1. **Unit Test:** Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
  2. **Assignments / Case Study:** Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
  3. **Seminar Presentation:** Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
  4. **Open Book Test:** Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

B) <u>End-Semester Examination (ESE)</u>

Detailed Scheme for 60 Marks: Unit-Wise Allocation (12 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Detailed Scheme for 40 Marks: Unit-Wise Allocation (08 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation The following structure is to be followed for designing an ESE for a **theory subject of 60 marks** covering **all 5 units** of the syllabus, with **questions set as per Bloom's Taxonomy** guidelines and **12 marks allocated per unit**.

2. Balanced Coverage

Ensure balanced coverage of all units with questions that assess different **cognitive levels of Bloom's Taxonomy**:

a) **Remembering**: Basic recall of facts and concepts.

b) **Understanding**: Explanation of ideas or concepts.

c) **Applying**: Use of information in new situations.

d) **Analyzing**: Drawing connections among ideas.

e) **Evaluating**: Justifying a decision or course of action.

f) **Creating**: Producing new or original work (if applicable).

Curriculum Structure
Honor Courses (2024 Pattern)
NEP 2020 Compliant Curriculum Structure

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Third and Final Year Mechanical Engineering (2024 pattern)

Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits			
			L	T	P	CCE	ESE	TW	OR	PR	TOTAL	L	T	P	TOTAL
Semester-V															
HLEA301MEC	Honor Course	Lean Manufacturing Principles and Systems		3		30	70				100		3		4
HLEA302MEC	Honor Course	Lean Manufacturing Laboratory			1			50			50			1	
Semester-VI															
HLEA351MEC	Honor Course	Lean Tools and Industrial Applications		3		30	70				100		3		4
HLEA352MEC	Honor Course	Value Stream Mapping & Simulation Laboratory			1			50			50			1	
Semester-VII															
HLEA401MEC	Honor Course	Lean Six Sigma and Quality Engineering		3		30	70				100		3		5
HLEA402MEC	Honor Course	Lean Six Sigma Mini Project			2			50			50			2	
Semester-VIII															
HLEA451MEC	Honor Course	Smart Lean Manufacturing and Digital Factory		3		30	70				100		3		5
HLEA452MEC	Honor Course	Industry Lean Improvement Project			2			50			50			2	
		Total		**12**	**06**	**120**	**280**	**200**			**600**		**12**	**06**	**18**

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

SEMESTER- V

Honor Courses

[Lean Manufacturing]

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HLEA301MEC: Lean Manufacturing Principles and Systems

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

- **Prerequisites:** Manufacturing processes, Production Engineering, Industrial Engineering and Basic Quality Concepts

Course Objectives:

After completing this course, students will be able to:

1. Understand the evolution of manufacturing systems and the philosophy of Lean Manufacturing.
2. Explain the principles and tools of the Toyota Production System (TPS).
3. Identify wastes and analyze manufacturing processes using Lean concepts.
4. Design efficient production systems by applying Lean techniques.

Develop the ability to evaluate Lean performance and recommend continuous improvement strategies.

Course Outcomes: On completion of the course, Student will be able to

CO1: Explain Lean philosophy, manufacturing evolution, and Toyota Production System.

CO2: Identify value and different types of waste in manufacturing systems.

CO3: Design Lean production systems using flow, pull, takt time, and cellular manufacturing concepts.

CO4: Evaluate manufacturing performance using Lean metrics and key performance indicators.

CO5: Recommend Lean implementation strategies through Lean culture, leadership, and Kaizen practices.

Course Contents

Unit I	Evolution of Manufacturing	(08 Hours)

Evolution of manufacturing systems, craft production, mass production, world class manufacturing (WCM), Lean manufacturing, philosophy, objectives and benefits of Lean manufacturing, Toyota Production System (TPS), House of Toyota, pillars of TPS including Just-in-Time (JIT) and Jidoka, continuous improvement philosophy, comparison of conventional and Lean manufacturing systems.

CCE Activities:

Explain the evolution of manufacturing systems, distinguish between craft, mass and Lean production, describe the Toyota Production System and its key elements, and discuss the benefits of Lean manufacturing.

Unit II	Lean Principles	(08 Hours)

Lean thinking and the five Lean principles, customer value, value-added and non-value-added activities, value stream, value stream mapping (introduction), flow, pull production system, push versus pull production, perfection, continuous improvement and customer-focused manufacturing

CCE Activities:

Explain the five Lean principles, identify value-added and non-value-added activities, differentiate between push and pull production systems, and interpret the basic concepts of value stream mapping.

Unit III	Waste Identification and Lean Metrics	(08 Hours)
Lean waste concepts, seven wastes (Muda), unevenness (Mura), overburden (Muri), identification and elimination of waste, Lean performance metrics, productivity, cycle time, lead time, throughput, Overall Equipment Effectiveness (OEE), first pass yield (FPY), and continuous performance monitoring		
CCE Activities: Identify different types of manufacturing waste, analyze processes for waste elimination, calculate basic Lean performance metrics, and evaluate manufacturing performance using Lean indicators.		
Unit IV	**Lean Production Systems**	**(08 Hours)**
Cellular manufacturing, group technology (introduction), one-piece flow, continuous flow manufacturing, line balancing, takt time, cycle time, standard work, workstation design, production flow optimization, and principles of efficient production system design.		
CCE Activities: Design simple Lean production systems, calculate takt time and cycle time, perform basic line balancing, and improve production flow using Lean techniques		
Unit V	**Lean Organization and Continuous Improvement**	**(08 Hours)**
Lean organization, Lean culture, Lean leadership, employee involvement, Kaizen philosophy, continuous improvement process, daily management practices, Lean transformation, barriers to Lean implementation, and critical success factors for sustainable Lean implementation.		
CCE Activities: Explain the importance of Lean culture and leadership, describe Kaizen and continuous improvement practices, evaluate organizational readiness for Lean implementation, and recommend Lean implementation strategies for manufacturing organizations		

Learning Resources

Text Books

1. Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill Education, Latest Edition.
2. Dennis, P., Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System, CRC Press, Latest Edition.
3. Shingo, S., A Study of the Toyota Production System, Productivity Press, Latest Edition.
4. Womack, J. P., Jones, D. T. and Roos, D., The Machine That Changed the World, Simon & Schuster, Latest Edition.

Ohno, T., Toyota Production System: Beyond Large-Scale Production, Productivity Press, Latest Edition

Reference Books

1. Womack, J. P. and Jones, D. T., Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Simon & Schuster, Latest Edition.
2. Rother, M. and Shook, J., Learning to See: Value Stream Mapping to Create Value and Eliminate Muda, Lean Enterprise Institute, Latest Edition.
3. Hobbs, D. P., Lean Manufacturing Implementation: A Complete Execution Manual for Any Size Manufacturer, J. Ross Publishing, Latest Edition.
4. Bicheno, J. and Holweg, M., The Lean Toolbox, Picsie Books, Latest Edition.
5. Wilson, L., How to Implement Lean Manufacturing, McGraw-Hill Education, Latest Edition.

George, M. L., Lean Six Sigma: Combining Six Sigma Quality with Lean Production Speed, McGraw-Hill Education, Latest Edition.

Web References

1. Lean Enterprise Institute (LEI) – https://www.lean.org
2. Toyota Global – Toyota Production System – https://global.toyota
3. The Toyota Way – https://global.toyota/en/company/vision-and-philosophy/toyota-production-system/https://onlinecourses.nptel.ac.in/noc22_me108/preview

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HLEA302MEC: Lean Manufacturing Laboratory

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**ESE**	**NA**
Practical	**2 Hours/Week**		**TW**	**50 Marks**

- **Prerequisites:** Basic knowledge of Manufacturing Processes, Industrial Engineering, Production Systems, and Lean Manufacturing Principles.

Course Objectives:

After completing this course, students will be able to:

5. Understand and apply fundamental Lean Manufacturing tools in a laboratory and industrial environment.
6. Develop skills in identifying and eliminating waste from manufacturing processes.
7. Perform work measurement and productivity improvement studies.
8. Apply Lean tools for workplace organization and continuous improvement.

Evaluate manufacturing performance using Lean metrics.

Course Outcomes: On completion of the course, Student will be able to

CO1: APPLY Lean tools for workplace organization and waste elimination.

CO2: PERFORM time study, motion study, and work standardization.

CO3: EVALUATE takt time, line balancing efficiency, and OEE.

CO4: IMPLEMENT Kaizen and Visual Management for process improvement.

CO5: ANALYZE manufacturing performance using Lean principles.

Guidelines for Laboratory Conduction

The student shall complete the following hands-on activities as a Term Work under the guidance of concerned faculty member. The open source software shall be preferred for conduction of practical

Term Work

The learner shall complete minimum 08 of the following activities as a Term-Work:

List of Practical

1. Implementation of **5S** methodology in laboratory/workshop.
2. Identification and classification of manufacturing wastes (Muda, Mura, Muri).
3. Time Study using stopwatch and work sampling techniques.
4. Motion Study using process charts and motion economy principles.
5. Development of Standard Work Instructions (SOPs).
6. Assembly Line Balancing using precedence diagrams.
7. Calculation of Takt Time, Cycle Time, and Production Rate.
8. Kaizen activity for continuous process improvement.
9. Design and implementation of Visual Management systems.
10. Overall Equipment Effectiveness (OEE) calculation using production data.

Learning Resources

Text Books

1. Womack, J. P., Jones, D. T., and Roos, D., The Machine That Changed the World, Free Press, New York.
2. Womack, J. P. and Jones, D. T., Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Simon & Schuster.
3. Ohno, T., Toyota Production System: Beyond Large-Scale Production, Productivity Press.
4. Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill.
5. Imai, M., Kaizen: The Key to Japan's Competitive Success, McGraw-Hill.

Reference Books

1. Monden, Y., Toyota Production System: An Integrated Approach to Just-In-Time, CRC Press.
2. Rother, M. and Shook, J., Learning to See: Value-Stream Mapping to Add Value and Eliminate MUDA, Lean Enterprise Institute.
3. Feld, W. M., Lean Manufacturing: Tools, Techniques, and How to Use Them, CRC Press.
4. Galsworth, G. D., Visual Workplace, Visual Thinking, Productivity Press.
5. Suzaki, K., The New Manufacturing Challenge: Techniques for Continuous Improvement, Free Press.

Web References

1. Lean Enterprise Institute (LEI) – Lean Manufacturing concepts and resources https://www.lean.org/
2. Lean Enterprise Institute – Lean Lexicon – Definitions of Lean tools and terminology Lean Lexicon https://www.lean.org/explore-lean/lexicon-terms/
3. American Society for Quality (ASQ) – Quality, Lean and Six Sigma resources ASQ Quality Resources https://asq.org/quality-resources
4. ASQ – 5S Tutorial – 5S methodology and implementation https://asq.org/quality-resources/five-s-tutorial
5. ASQ 5S Tutorial https://global.toyota/en/company/vision-and-philosophy/production-system/

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

SEMESTER- VI

Honor Courses

[Lean Manufacturing]

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HLEA351MEC: Lean Tools and Industrial Applications

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End-Semester	70 Marks

- **Prerequisites:** Manufacturing processes, Production Engineering, Industrial Engineering and Production Planning and Control

Course Objectives:

After completing this course, students will be able to:

1. Understand the purpose and application of Lean tools for improving manufacturing performance.
2. Apply Lean techniques to eliminate waste, improve productivity, and enhance quality.
3. Analyze manufacturing systems using Value Stream Mapping and Lean performance measures.
4. Develop the ability to solve industrial problems using Lean methodologies.
5. Evaluate Lean implementation through industrial case studies and best practices.

Course Outcomes: On completion of the course, Student will be able to

CO1: Explain the concepts and applications of major Lean tools used in manufacturing industries.

CO2: Apply Lean tools such as 5S, Kanban, Standard Work, Poka-Yoke, and Visual Management to improve manufacturing processes.

CO3: Analyze manufacturing systems using Value Stream Mapping, OEE, TPM, and SMED

CO4: Evaluate Lean implementation and operational performance using industrial case studies.

CO5: Recommend suitable Lean improvement strategies for industrial applications.

Course Contents

Unit I	Workplace Organization and Visual Lean Tools	(08 Hours)

Introduction to Lean tools, workplace organization using 5S methodology, workplace discipline and standardization, Visual Management principles, visual controls, workplace communication, Standard Work, work instructions, standard operating procedures (SOPs), work standardization, ergonomics in Lean workplaces.

CCE Activities:

Introduction to Lean tools, workplace organization using 5S methodology, workplace discipline and standardization, Visual Management principles, visual controls, workplace communication, Standard Work, work instructions, standard operating procedures (SOPs), work standardization, ergonomics in Lean workplaces.

Unit II	Quality and Flow Improvement Tools	(08 Hours)

Poka-Yoke (mistake proofing), types of Poka-Yoke devices, Jidoka (automation with a human touch), autonomous quality control, Kanban system, pull production, types of Kanban, Heijunka (production leveling), inventory reduction, production flow improvement.

CCE Activities:

Explain quality assurance through Poka-Yoke and Jidoka, apply Kanban for pull production systems, describe Heijunka for production leveling, and analyze the role of Lean tools in improving manufacturing flow.

Unit III	Equipment and Process Improvement	(08 Hours)

Single Minute Exchange of Dies (SMED), setup time reduction, internal and external setup activities, Total Productive Maintenance (TPM), eight pillars of TPM, autonomous maintenance, planned maintenance, Overall Equipment Effectiveness (OEE), calculation and interpretation of OEE, equipment reliability and productivity improvement

CCE Activities:
Apply SMED techniques to reduce setup time, explain TPM concepts and pillars, calculate Overall Equipment Effectiveness, and evaluate equipment performance for productivity improvement

Unit IV	Value Stream Mapping and Lean Shop Floor Management	(08 Hours)

Value Stream Mapping (VSM), current state mapping, future state mapping, identification of value-added and non-value-added activities, Gemba philosophy, Gemba walk, problem identification at the workplace, Andon system, visual signaling, production monitoring, continuous improvement using shop floor management.

CCE Activities:
Design simple Lean production systems, calculate takt time and cycle time, perform basic line balancing, and improve production flow using Lean techniques

Unit V	Lean Manufacturing Applications and Case Studies	(08 Hours)

Lean implementation strategies in manufacturing industries, industrial case studies on Lean implementation, Lean practices adopted by Toyota, Tata Motors, Mahindra, Bosch, John Deere, and Cummins, challenges in Lean implementation, benefits of Lean transformation, best practices and future trends in Lean manufacturing.

CCE Activities:
Evaluate Lean implementation using industrial case studies, compare Lean practices across industries, identify critical success factors for Lean transformation, and recommend Lean improvement strategies for manufacturing organizations.

Learning Resources

Text Books

5. Dennis, P., Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System, CRC Press, Latest Edition.
6. Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill Education, Latest Edition.
7. Shingo, S., A Revolution in Manufacturing: The SMED System, Productivity Press, Latest Edition.
8. Rother, M. and Shook, J., Learning to See: Value Stream Mapping to Add Value and Eliminate Muda, Lean Enterprise Institute, Latest Edition.

Nakajima, S., Introduction to TPM: Total Productive Maintenance, Productivity Press, Latest Edition.

Reference Books

6. Womack, J. P. and Jones, D. T., Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Simon & Schuster, Latest Edition.
7. Wilson, L., How to Implement Lean Manufacturing, McGraw-Hill Education, Latest Edition.
8. Bicheno, J. and Holweg, M., The Lean Toolbox, Picsie Books, Latest Edition.
9. Hobbs, D. P., Lean Manufacturing Implementation: A Complete Execution Manual for Any Size Manufacturer, J. Ross Publishing, Latest Edition.
10. Imai, M., Gemba Kaizen: A Commonsense, Low-Cost Approach to Management, McGraw-Hill Education, Latest Edition.

George, M. L., Lean Six Sigma, McGraw-Hill Education, Latest Edition.

Web References

1. https://www.lean.org (Lean Enterprise Institute)
2. https://global.toyota (Toyota Global – Toyota Production System)
3. https://asq.org (American Society for Quality)
4. https://www.sme.org (Society of Manufacturing Engineers)
5. https://www.iise.org (Institute of Industrial and Systems Engineers)
6. https://www.nist.gov/mep (NIST Manufacturing Extension Partnership)
7. https://nptel.ac.in (NPTEL)
8. https://swayam.gov.in (SWAYAM)
9. https://www.isixsigma.com (Lean Six Sigma Articles and Case Studies

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

HLEA352MEC: Value Stream Mapping & Simulation Laboratory

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**ESE**	**NA**
Practical	**2 Hours/Week**		**TW**	**50 Marks**

- **Prerequisites:** Knowledge of Lean Manufacturing, Manufacturing Systems, Production Planning, and Basic Computer Applications.

Course Objectives:

After completing this course, students will be able to:

1. Develop Value Stream Maps for manufacturing systems.
2. Analyze manufacturing processes for waste and bottlenecks.
3. Apply simulation tools for process improvement.
4. Evaluate production capacity and lead time reduction opportunities.
5. Recommend Lean improvements using digital tools

Course Outcomes: On completion of the course, Student will be able to

CO1: DEVELOP current and future state Value Stream Maps.

CO2: ANALYZE manufacturing processes using Lean mapping techniques.

CO3: ANALYZE bottleneck and capacity using simulation software.

CO4: EVALUATE lead time reduction opportunities.

CO5: RECOMMEND Lean improvements using simulation results.

Guidelines for Laboratory Conduction

The student shall complete the following hands-on activities as a Term Work under the guidance of concerned faculty member. The open source software shall be preferred for conduction of practical

Term Work

The learner shall complete minimum 08 of the following activities as a Term-Work

List of Practical

1. Preparation of Process Flow Diagram for a Manufacturing System.
2. Process Mapping of Manufacturing Operations.
3. Preparation of Current-State Value Stream Map (VSM).
4. Preparation of Spaghetti Diagram for Material and Operator Movement.
5. Calculation of Process Cycle Time, Lead Time, and Value-Added Time.
6. Identification and Analysis of Bottlenecks in a Manufacturing Process.
7. Preparation of Future-State Value Stream Map (VSM).
8. Manufacturing Process Simulation using FlexSim, Arena, or AnyLogic.
9. Capacity Analysis of a Manufacturing Production System using Simulation.
10. Lead Time Reduction through Lean Improvement Proposals.

Learning Resources

Text Books

1. Rother, M. and Shook, J., Learning to See: Value-Stream Mapping to Add Value and Eliminate MUDA, Lean Enterprise Institute.
2. Womack, J. P. and Jones, D. T., Lean Thinking: Banish Waste and Create Wealth in Your Corporation, Simon & Schuster.
3. Dennis, P., Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System, Productivity Press.
4. Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill.
5. Banks, J., Carson, J. S., Nelson, B. L. and Nicol, D. M., Discrete-Event System Simulation, Pearson.

Reference Books

1. Ohno, T., Toyota Production System: Beyond Large-Scale Production, Productivity Press.
2. Monden, Y., Toyota Production System: An Integrated Approach to Just-In-Time, CRC Press.
3. Feld, W. M., Lean Manufacturing: Tools, Techniques, and How to Use Them, CRC Press.
4. George, M. L., Lean Six Sigma: Combining Six Sigma Quality with Lean Speed, McGraw-Hill.
5. Goldratt, E. M. and Cox, J., The Goal: A Process of Ongoing Improvement, North River Press.
6. Hopp, W. J. and Spearman, M. L., Factory Physics, Waveland Press.

Web References

1. https://www.lean.org/
2. https://www.flexsim.com/
3. https://www.rockwellautomation.com/en-us/products/software/arena-simulation.html
4. https://www.anylogic.com/
5. https://app.diagrams.net/

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Savitribai Phule Pune University, Pune

Maharashtra, India

BE - Mechanical Engineering (2024 Pattern)

SEMESTER- VII

Honor Courses

[Lean Manufacturing]

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HLEA401MEC: Lean Six Sigma and Quality Engineering

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

- **Prerequisites:** Lean Manufacturing Principles, Manufacturing processes, Engineering Statics and Probability, Industrial Engineering and Basic Quality Concepts

Course Objectives:

After completing this course, students will be able to:

1. Understand the integration of Lean Manufacturing and Six Sigma methodologies for process improvement.
2. Apply statistical quality control tools to monitor and improve manufacturing processes.
3. Analyze process capability and identify root causes of quality problems.
4. Apply quality engineering tools for process optimization and risk reduction.
5. Recommend Lean Six Sigma solutions for continuous quality improvement in manufacturing industries.

Course Outcomes: On completion of the course, Student will be able to

CO1: Explain Lean Six Sigma concepts, DMAIC methodology, and statistical thinking for quality improvement.

CO2: Apply statistical process control tools and process capability analysis to monitor manufacturing processes.

CO3: Analyze quality problems using root cause analysis, Fishbone diagram, 5 Why analysis, and FMEA.

CO4: Evaluate manufacturing processes using Design of Experiments (DOE), cost of quality, and Lean quality metrics.

CO5: Recommend Lean Six Sigma solutions for continuous quality improvement and operational excellence

Course Contents

Unit I	Introduction to Lean Six Sigma	(08 Hours)

Introduction to quality engineering, Lean versus Six Sigma, integration of Lean and Six Sigma, benefits of Lean Six Sigma, customer focus and critical-to-quality (CTQ) characteristics, DMAIC methodology including Define, Measure, Analyze, Improve and Control phases, statistical thinking, variation in manufacturing processes, process improvement methodology.

CCE Activities:

Explain Lean Six Sigma philosophy, compare Lean and Six Sigma approaches, describe the DMAIC methodology, and explain the importance of statistical thinking in quality improvement.

Unit II	Statistical Process Control and Process Capability	(08 Hours)

Statistical Process Control (SPC), common cause and special cause variation, control charts for variables and attributes, $\bar{X}$ chart, R chart, S chart, p chart, np chart, c chart and u chart, interpretation of control charts, process capability, process capability indices (Cp, Cpk, Pp and Ppk), process stability and capability analysis.

CCE Activities:
Apply statistical process control techniques, construct and interpret control charts, calculate process capability indices, and evaluate process stability and capability.

Unit III	Root Cause Analysis and Risk Assessment	(08 Hours)

Problem-solving methodology, root cause analysis, Fishbone (Ishikawa) diagram, 5 Why analysis, Failure Mode and Effects Analysis (FMEA), severity, occurrence and detection ratings, Risk Priority Number (RPN), corrective and preventive actions (CAPA), continuous quality improvement.

CCE Activities:
Analyze quality problems using root cause analysis tools, develop Fishbone diagrams, perform 5 Why analysis, conduct FMEA studies, and recommend corrective actions to minimize process risks.

Unit IV	Design of Experiments and Quality Cost	(08 Hours)

Introduction to Design of Experiments (DOE), objectives and benefits of DOE, factors, levels and responses, full factorial and fractional factorial designs, screening experiments, optimization of process parameters, cost of quality, prevention cost, appraisal cost, internal failure cost, external failure cost, quality cost analysis and economic impact of quality improvement.

CCE Activities:
Explain the principles of Design of Experiments, identify process factors affecting quality, analyze cost of quality components, and evaluate process improvement opportunities using quality engineering tools.

Unit V	Lean Quality Improvement and Industrial Applications	(08 Hours)

Lean quality improvement strategies, integration of Lean tools with Six Sigma, defect reduction, waste elimination, process optimization, customer satisfaction, continuous improvement, quality culture, Lean Six Sigma implementation roadmap, industrial applications and case studies in manufacturing industries, challenges and success factors in Lean Six Sigma implementation.

CCE Activities:
Evaluate Lean Six Sigma implementation strategies, recommend quality improvement initiatives, analyze industrial case studies, and develop solutions for achieving operational excellence.

Learning Resources

Text Books

1. George, M. L., Lean Six Sigma: Combining Six Sigma Quality with Lean Production Speed, McGraw-Hill Education, Latest Edition.
2. Montgomery, D. C., Introduction to Statistical Quality Control, John Wiley & Sons, Latest Edition.
3. Pyzdek, T. and Keller, P. A., The Six Sigma Handbook, McGraw-Hill Education, Latest Edition.
4. Breyfogle, F. W., Implementing Six Sigma: Smarter Solutions Using Statistical Methods, Wiley, Latest Edition.
5. Juran, J. M. and De Feo, J. A., Juran's Quality Handbook, McGraw-Hill Education, Latest Edition.

Reference Books

1. Montgomery, D. C., Design and Analysis of Experiments, John Wiley & Sons, Latest Edition.
2. Evans, J. R. and Lindsay, W. M., Managing for Quality and Performance Excellence, Cengage Learning, Latest Edition.
3. Besterfield, D. H., Quality Control, Pearson Education, Latest Edition.
4. Imai, M., Gemba Kaizen: A Commonsense, Low-Cost Approach to Management, McGraw-Hill Education, Latest Edition.
5. Liker, J. K., The Toyota Way, McGraw-Hill Education, Latest Edition.
6. Oakland, J. S., Statistical Process Control, Routledge, Latest Edition.

Web References
1. American Society for Quality (ASQ) – https://asq.org 2. Lean Enterprise Institute (LEI) – https://www.lean.org 3. Institute of Industrial and Systems Engineers (IISE) – https://www.iise.org 4. NIST Manufacturing Extension Partnership (MEP) – https://www.nist.gov/mep 5. Society of Manufacturing Engineers (SME) – https://www.sme.org 6. NPTEL – https://nptel.ac.in 7. SWAYAM – https://swayam.gov.in 8. iSixSigma – https://www.isixsigma.com 9. AIAG (Automotive Industry Action Group) – https://www.aiag.org 10. Minitab Resources – https://support.minitab.com

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HLEA402MEC: Lean Six Sigma Mini Project

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	2	OR	NA
Practical	2 Hours/Week		TW	50 Marks

- **Prerequisites:** Manufacturing Processes, Industrial Engineering, Production Planning & Control, Engineering Statistics, Quality Control, Metrology and Inspection, Engineering Economics, Operations Research, MS Excel or Minitab (Basic), CAD/Process Flow Documentation

Course Objectives:

After completing this course, students will be able to:

1. Understand the fundamentals of Lean Manufacturing and Six Sigma concepts.
2. Identify wastes, defects, and process improvement opportunities in manufacturing systems.
3. Apply Lean Six Sigma tools using the DMAIC methodology to solve industrial problems.
4. Analyze process data and recommend suitable improvement actions.
5. Execute a Lean Six Sigma mini project and present the results in a professional manner.

Course Outcomes: On completion of the course, Student will be able to

CO1: **EXPLAIN** Lean Manufacturing principles and Six Sigma concepts.

CO2: **IDENTIFY** manufacturing wastes and quality-related problems.

CO3: **APPLY** Lean Six Sigma tools through the DMAIC approach.

CO4: **ANALYZE** process data and evaluate improvement opportunities.

CO5: **DEVELOP** and present a Lean Six Sigma mini project for process improvement.

Course Contents

Students shall carry out one mini project in a manufacturing laboratory or industry using DMAIC methodology.

Stage-I: Topic Identification and Literature Survey

In this stage, the student is expected to understand and complete the following:

- Introduction to Lean Manufacturing
- Eight Wastes (TIMWOODS)
- Lean Six Sigma Concepts
- DMAIC Methodology
- Selection of Mini Project Topic and Literature survey.

Stage-II: Suggested Practical Activities

- Identification of wastes in laboratory/workshop
- Preparation of SIPOC Diagram
- Process Mapping
- Pareto Analysis
- Fishbone Diagram
- 5 Why Analysis
- 5S Audit
- Kaizen Suggestion
- Mini Project Presentation

Stage-III: Lean Six Sigma Mini Project

Students shall carry out one mini project in a manufacturing laboratory or industry using DMAIC methodology.

Suggested Project Areas

- Productivity Improvement
- Scrap Reduction
- Cycle Time Reduction
- Workplace Organization (5S)
- Setup Time Reduction
- Process Standardization
- Inventory Reduction
- Quality Improvement
- Machine Utilization
- Layout Improvement

Learning Resources

Reference Books

1. George, M. L., *Lean Six Sigma*, McGraw-Hill.
2. Womack, J. P. and Jones, D. T., *Lean Thinking*, Simon & Schuster.
3. Liker, J. K., *The Toyota Way*, McGraw-Hill.
4. Pyzdek, T. and Keller, P., *The Six Sigma Handbook*, McGraw-Hill.
5. Dennis, P., *Lean Production Simplified*, Productivity Press.

Journals or Transactions

Students are encouraged to refer recent research papers from:

- *International Journal of Lean Six Sigma*
- *Journal of Manufacturing Systems*
- *International Journal of Production Research*
- *Journal of Cleaner Production*
- *International Journal of Productivity and Performance Management*

Conference Proceedings

- *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*
- *CIRP Conference on Manufacturing Systems*
- *ASME Manufacturing Science and Engineering Conference (MSEC)*
- *IEOM International Conferenc*

Patents

- United States Patent and Trademark Office (USPTO).
- European Patent Office (EPO).
- World Intellectual Property Organization (WIPO – PATENTSCOPE).
- Indian Patent Advanced Search System (InPASS).

Web References

Savitribai Phule Pune University, Pune

Maharashtra, India

BE - Mechanical Engineering (2024 Pattern)

SEMESTER- VIII

Honor Courses

[Lean Manufacturing]

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HLEA451MEC: Smart Lean Manufacturing and Digital Factory

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

- **Prerequisites:** Lean Manufacturing Principles, Manufacturing processes, Engineering Statics and Probability, Industrial Engineering and Basic Automation

Course Objectives:

After completing this course, students will be able to:

1. Understand the concepts of Industry 4.0 and smart manufacturing technologies.
2. Explain the integration of Lean Manufacturing with digital manufacturing systems.
3. Apply digital tools for monitoring, controlling, and optimizing manufacturing operations.
4. Analyze manufacturing data using smart analytics for improved decision-making.
5. Evaluate industrial applications of Smart Lean Manufacturing in modern manufacturing enterprises.

Course Outcomes: On completion of the course, Student will be able to

CO1: Explain Industry 4.0 concepts, smart manufacturing technologies, and digital factory systems.

CO2: Apply digital technologies such as IoT, AI, Digital Twin, MES, ERP, RFID, and AGVs to support Lean manufacturing.

CO3: Analyze Lean manufacturing systems using smart analytics, dashboards, OEE analytics, and predictive maintenance techniques.

CO4: Evaluate the integration of Lean Manufacturing with Industry 4.0 for smart factory implementation

CO5: Recommend Smart Lean Manufacturing solutions for automotive, aerospace, and MSME industries

Course Contents

Unit I	Industry 4.0 and Smart Manufacturing	(08 Hours)

Evolution of industrial revolutions, Industry 4.0 concepts and principles, cyber-physical systems (CPS), Internet of Things (IoT), Artificial Intelligence (AI) in manufacturing, machine learning basics, Digital Twin, Digital Factory, Smart Factory, intelligent manufacturing systems, digital transformation in manufacturing industries

CCE Activities:

Explain the concepts of Industry 4.0, describe the role of IoT, AI, Digital Twin, Digital Factory, and Smart Factory, and discuss their significance in modern manufacturing systems.

Unit II	Lean Manufacturing and Industry 4.0 Integration	(08 Hours)

Integration of Lean Manufacturing with Industry 4.0, Lean 4.0 concepts, Smart Kanban systems, Digital Total Productive Maintenance (Digital TPM), Radio Frequency Identification (RFID), Automated Guided Vehicles (AGVs), Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), Cloud Manufacturing, digital workflow management, real-time production monitoring and control.

CCE Activities:

Explain the integration of Lean and Industry 4.0 technologies, apply digital manufacturing tools for production management, and evaluate their contribution to operational efficiency.

Unit III	Smart Manufacturing Analytics	(08 Hours)
Manufacturing data collection, industrial dashboards, Key Performance Indicators (KPIs), Overall Equipment Effectiveness (OEE) analytics, production analytics, predictive maintenance, condition monitoring, data-driven decision making, manufacturing intelligence, visualization of production performance, continuous monitoring of manufacturing systems.		
CCE Activities: Analyze manufacturing data using digital dashboards, interpret OEE analytics, explain predictive maintenance concepts, and recommend data-driven improvements for manufacturing performance		
Unit IV	**Digital Factory Systems**	**(08 Hours)**
Digital manufacturing systems, virtual factory concepts, simulation in manufacturing, digital production planning, smart inventory management, digital quality management, cloud-based manufacturing systems, industrial communication networks, industrial cybersecurity fundamentals, sustainable and connected manufacturing systems.		
CCE Activities: Explain the architecture of digital factory systems, analyze digital manufacturing workflows, evaluate digital production planning tools, and discuss cybersecurity considerations in smart manufacturing.		
Unit V	**Industrial Applications of Smart Lean Manufacturing**	**(08 Hours)**
Smart Lean Manufacturing implementation in automotive industries, aerospace manufacturing, MSMEs, digital transformation strategies, Industry 4.0 maturity models, implementation challenges, benefits of Smart Lean Manufacturing, sustainability, future trends in intelligent manufacturing, industrial case studies and best practices..		
CCE Activities: Evaluate Smart Lean Manufacturing implementation across different industries, analyze industrial case studies, identify challenges in digital transformation, and recommend Smart Lean solutions for manufacturing organizations		

Learning Resources

Text Books

1. Gilchrist, A., Industry 4.0: The Industrial Internet of Things, Apress, Latest Edition.
2. Kolberg, D., Zühlke, D. and Vogel-Heuser, B., Smart Manufacturing Systems, Springer, Latest Edition.
3. Liker, J. K., The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer, McGraw-Hill Education, Latest Edition.
4. Shrouf, F., Ordieres, J. and Miragliotta, G., Smart Factories in Industry 4.0: A Review, Springer, Latest Edition.
5. Buer, S. V., Strandhagen, J. O. and Chan, F. T. S., The Link between Industry 4.0 and Lean Manufacturing: Mapping Current Research and Establishing a Research Agenda, Springer, Latest Edition.

Reference Books

1. Kagermann, H., Wahlster, W. and Helbig, J., Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0, German National Academy of Science and Engineering (acatech).
2. Monostori, L., Cyber-Physical Production Systems, Springer, Latest Edition.
3. Lee, J., Bagheri, B. and Kao, H. A., A Cyber-Physical Systems Architecture for Industry 4.0-Based Manufacturing Systems, Springer, Latest Edition.
4. Imai, M., Gemba Kaizen: A Commonsense, Low-Cost Approach to Management, McGraw-Hill Education, Latest Edition.
5. George, M. L., Lean Six Sigma, McGraw-Hill Education, Latest Edition.
6. Brettel, M., Friederichsen, N., Keller, M. and Rosenberg, M., How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: Industry 4.0 Perspective, Springer, Latest Edition.

Web References
1. Industry 4.0 Platform (Plattform Industrie 4.0) – https://www.plattform-i40.de 2. National Institute of Standards and Technology (NIST) – https://www.nist.gov 3. Smart Manufacturing Leadership Coalition (SMLC) – https://www.smartmanufacturingcoalition.org 4. Society of Manufacturing Engineers (SME) – https://www.sme.org 5. Lean Enterprise Institute (LEI) – https://www.lean.org 6. American Society for Quality (ASQ) – https://asq.org 7. NPTEL – https://nptel.ac.in 8. SWAYAM – https://swayam.gov.in 9. Siemens Digital Industries – https://www.siemens.com/digitalindustrie 10. PTC Digital Manufacturing – https://www.ptc.com

Savitribai Phule Pune University
Final Year of Mechanical Engineering (2024 Pattern)

HLEA452MEC: Industry Oriented lean Manufacturing Project

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**2**	**OR**	**NA**
Practical	**2 Hours/Week**		**TW**	**50 Marks**

- **Prerequisites:** Fundamentals of Manufacturing Processes , Lean Manufacturing Principles , Industrial Engineering , Quality Engineering , Production Planning and Control , Basics of Industry 4.0 and Smart Manufacturing

Course Objectives:

After completing this course, students will be able to:

1. Identify real industrial manufacturing problems through systematic shop-floor study and Lean assessment.
2. Apply Lean Manufacturing tools and Industry 4.0 technologies to improve productivity, quality, cost, and delivery.
3. Analyze manufacturing systems using Value Stream Mapping (VSM), Overall Equipment Effectiveness (OEE), Key Performance Indicators (KPIs), and digital manufacturing tools-.
4. Develop innovative, sustainable, and industry-oriented solutions using Kaizen, TPM, SMED, 5S, Digital Kanban, and Smart Manufacturing concepts.
5. Demonstrate professional skills in project planning, technical documentation, teamwork, presentation, and industrial problem solving.

Course Outcomes: On completion of the course, Student will be able to

CO1: Identify manufacturing problems and prepare an industry-oriented Lean project plan

CO2: Apply Lean Manufacturing tools to eliminate waste and improve production performance.

CO3: Analyze manufacturing systems using digital technologies, OEE, KPIs, and data-driven approaches.

CO4: Design and validate Lean improvement solutions integrating Industry 4.0 concepts.

CO5: Prepare a professional project report and effectively communicate technical outcomes through presentations and demonstrations.

Course Contents

The evaluation of the Industry Oriented lean Manufacturing Project is proposed through the following stages.

Stage-I: Problem Identification and Project Planning

In this stage, the student (or student group) is expected to complete the following:

- Select an industry or manufacturing process for study.
- Identify a real industrial problem related to productivity, quality, inventory, maintenance, safety, energy, or waste elimination.
- Prepare the Project Charter, Literature Survey, SIPOC Diagram, Current Process Flow, and Project Schedule.

Stage-II: Lean System Analysis

In this stage, the student is expected to complete the following:

- Conduct Value Stream Mapping (Current State), 5S Audit, Waste Identification, Time Study, Motion Study, and Root Cause Analysis.
- Evaluate production performance using KPIs, Cycle Time, Takt Time, and Overall Equipment Effectiveness (OEE).
- Analyze existing manufacturing practices and identify improvement opportunities using Lean tools.

Stage-III: Development and Implementation of Improvement Plan

In this stage, the student is expected to complete the following:

- Develop Lean improvement solutions using Kaizen, SMED, TPM, Poka-Yoke, Visual Management, Standard Work, Cellular Manufacturing, or Digital Kanban.
- Integrate Industry 4.0 technologies such as IoT, MES, ERP, RFID, Digital Dashboards, or Smart Monitoring wherever applicable.
- Prepare Future State Value Stream Mapping and estimate productivity improvement, cost reduction, and quality enhancement.

Stage-IV: Validation, Documentation and Presentation

In this stage, the student is expected to complete the following:

- Validate project outcomes through industrial data analysis and comparison with the existing system.
- Prepare the final technical report, presentation, and project demonstration.
- Present project findings before faculty and industry experts with recommendations for future implementation.

Term Work

The term work shall consist of the following:

1. The student shall prepare a duly certified project report in the standard institute format.
2. Literature survey and review of relevant journal papers.
3. Industrial visit and problem identification report.
4. Lean analysis report including VSM, OEE, KPIs, and Waste Analysis.
5. Implementation report showing proposed or validated improvements.
6. Future State Value Stream Map and Cost-Benefit Analysis.
7. Presentation and demonstration before the departmental committee.
8. Maintenance of project diary and regular progress reviews.

Examination Scheme:

During university examination Internal examiner (preferably the guide) and External examiners jointly, evaluate the project work.

Component	**Marks**
TERM WORK	
Problem Identification & Planning	05
Literature Survey	05
Lean Analysis & Data Collection	10
Design/Development of Solution	10
Implementation & Validation	10
Project Report	10
ORAL	
Presentation & Viva-Voce	50
Total	**100**

Reference Books

1. Jeffrey K. Liker, *The Toyota Way*, McGraw-Hill Education.
2. James P. Womack and Daniel T. Jones, *Lean Thinking*, Simon & Schuster.
3. Michael L. George, *Lean Six Sigma*, McGraw-Hill.
4. Masaaki Imai, *Gemba Kaizen*, McGraw-Hill Education.
5. Gilchrist, A., *Industry 4.0: The Industrial Internet of Things*, Apress.
6. Kolberg, D., Zühlke, D., *Smart Manufacturing Systems*, Springer.
7. Dennis P. Hobbs, *Lean Manufacturing Implementation*, J. Ross Publishing.
8. Rother, M. and Shook, J., *Learning to See: Value Stream Mapping*, Lean Enterprise Institute.

Web References

1. Lean Enterprise Institute – https://www.lean.org
2. Society of Manufacturing Engineers – https://www.sme.org
3. National Institute of Standards and Technology (NIST) – https://www.nist.gov
4. Plattform Industrie 4.0 – https://www.plattform-i40.de
5. Smart Manufacturing Leadership Coalition – https://www.smartmanufacturingcoalition.org
6. Siemens Digital Industries – https://www.siemens.com/digitalindustries
7. PTC Digital Manufacturing – https://www.ptc.com
8. NPTEL – https://nptel.ac.in
9. SWAYAM – https://swayam.gov.in

Task Force for Curriculum Design and Development

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