OPRE 6319: AI in Manufacturing, Fall 2025

Professor Kathryn E. Stecke

Course Pack

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OPRE 6319: AI in Manufacturing **Fall 2025 (Thursdays, 4:00-6:45 PM)**

Professor Kathryn E. Stecke

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Course Synopsis

U.S. manufacturing companies can be threatened by radical changes in the competitiveness within their industries. This course covers both the design and efficient operation of a variety of manufacturing system types, including fully automated and manual manufacturing, integrated circuit fabrication and assembly, and robotics systems. Recent as well as future sophisticated machine learning approaches to, first design appropriate production systems and after, produce the desired products on these systems, are discussed. Examples of production systems from all over the world are presented to show the wide variety of system designs and problems. Quantum Computing to schedule real job shops is covered. Expert Guest Speakers are scheduled. AI approaches in manufacturing can be further explored in Group Projects. A group paper and group presentation are required. The course consists of lectures, cases, films, discussion, and a plant tour to Texas Instruments. There is a course pack, but no textbook.

A special half-day session will be a tour of the fully automated manufacturing systems at the Texas Instruments RFAB Wafer Fab Plant on **Friday, October 31** to see first-hand what unique operational problems (and opportunities) exist. It is an integrated circuit manufacturing facility. The RFAB tour includes an introduction to Texas Instruments and the semiconductor manufacturing process. You will see an overview of a device from start to finished product and some of the many aspects of a 300mm factory. You will see a wafer up close and a peek into TI's first 300mm cleanroom. Detailed discussions with the system managers and operators can take place.

Part of the course focuses on operational and engineering issues and problems, and includes case analyses to demonstrate the problems actually faced. We learn by analyzing the case situations of real firms as they fumble, or succeed, in dealing with the opportunities that are potentially available from the new technologies. We also learn from the readings, lectures, tour, and group presentations on particular topics.

General Information

The course reading materials come from the cases and readings in the Course Pack, some online, and in some handouts during the semester. There is no required textbook. I am in my office most afternoons and evenings. Please stop by (**JSOM 2.422**), call me (**972-883-4781**), or leave me a note.

In order to emphasize the role of the general manager in operations and engineering in a modern manufacturing environment, some cases will be used. In each instance, there will be a decision orientation with a specific manager or group of managers having responsibility to develop specific action plans. **One objective of this course** is to help you to understand how modern operations function within a firm, the primary tasks that must be dealt with in different environments, and the ways in which operations can be organized to accomplish these tasks.

Another objective of the course is to improve your decision-making ability for complex situations. Contemporary operations consist of knowledge, technology, capital, and human resources that interact with one another, and any proposal must consider system-wide consequences. Managers are paid for making decisions and not only for performing analyses; however, studies indicate that managers who perform extensive analysis consistently make better decisions than their "*shoot from the hip*" counterparts.

Some additional particular *objectives* of this course are to:

1. Develop a managerial point of view--a capacity for analyzing problems in technologically advanced systems on a functional, business unit, and company-wide basis.
2. Integrate the knowledge gained in previous courses and extend that into the area of contemporary manufacturing problems.
3. Suggest the range of general management issues that must be considered in technologically advanced enterprises in effectively handling individual operating decisions with a strategic point of view.

Course Preparation

Each small group of four to six students will write a short, applied research paper on a topic of the course or a related topic selected with the permission of the instructor. These will be on some mutually agreed upon topic. The main purposes of this group project are to let you explore in some detail a topic concerning AI and machine learning that is of interest to you, and to have the entire class learn from your research effort. Second, I am interested in having you polish your interpersonal and communication skills.

A proposal for the paper in the form of a title, a one-page summary of objectives, abstract, and expected outcomes for this topic is due by **Monday, November 3**. The final paper should not exceed 12 double-spaced pages, including references and supporting materials, such as exhibits, tables, figures, and/or appendices. The oral reports will be presented in class on **November 20** and the final paper due on **December 4**. Accompanying each written report could be copies of the overheads used in the oral presentation. Preparation and distribution of all materials (copies of overheads, if you like) to your classmates is the responsibility of each group. Topics will be accepted on a first-come/first-served basis, so it is in your interest to form your groups and select your topics as soon as possible, and by **November 3** at the latest.

Generative AI tools like ChatGPT do not need to be used. If you choose to use it after your entire 12-page report is finished, check what it "suggested" (in case it is nonsense or change what you meant to say). Include an acknowledgement of how and where you used it and the results (just after your list of references). Turnitin or other methods may be used to detect the use of AI. Inappropriate use of AI may result in penalties.

The final grade is determined by the midterm (40%), final paper and presentation (40%), and class participation (20%). I keep accurate records of class participation, which consists of any questions, comments, suggestions, and analyses that facilitate class learning. I evaluate the quality of your contribution, not how many times you speak.

In order to obtain the full benefit of the case approach, it is necessary that everyone comes to class well prepared for an intelligent and interesting class discussion. This does not mean that "you have solved the case" or "have all the answers" to the case. Given the complexities of the real world, there is no answer. However, it does mean that you have thoroughly read the case and other assigned materials, have intelligently thought about the issues raised by the case and associated assignment questions, and have done whatever quantitative analysis is appropriate. In class, your instructor will act as moderator, questioner, and lecturer to help guide the learning process. By actively participating in class discussions, you will sharpen your own insights, and those of your classmates. You will not only learn the "content" of the course, but perhaps more importantly, the "process" of analysis, formulation, and implementation.

Laptops and Cell Phones

Computers are often not useful for our case discussions. I know that some students like to take notes in class on their computers. Every term, some students complain to me that the sounds from laptop users are highly distracting to them. Also, there is research that shows that learning is enhanced from the process of manually taking notes in class. Therefore, laptop use is usually not allowed. They may possibly be used during some of the

Guest Lectures. Cell phones should always be turned off. If you must send or review a text, please leave the room.

Attendance

There are occasional legitimate conflicts that prevent a student from completely preparing or from attending class. If you are not able to fully prepare for class, please attend anyway and participate as best you can. But please tell me of your situation before class, so that I will not ask you questions that you are not prepared well enough to discuss. If you must miss a class, please inform me so that I understand your situation. By enrolling in this course, you are agreeing to do your best to attend and contribute to the group learning experience.

Reserve

The following books are on reserve in McDermott Library.

- Anil Ananthaswamy, Why Machines Learn: The Elegant Math Behind Modern AI, Dutton, NY (2024).
- Eric R. Johnston, Nic Harrigan, Mercedes Gimeno-Segovia, Programming Quantum Computers: Essential Algorithms and Code Samples, O'Reilly, Beijing (2019).

Course Outline

Session 1, **August 28** – *Course Introduction and Comparison of Job Shops and Flow Shops.*

Learning objectives for this session:
- **Introduce the spectrum of process types.**
- **Understand the general characteristics of job shops and flow shops.**
- **Introduce the trade-offs between efficiency and flexibility.**

An overview of the semester will be given. Then the spectrum of manufacturing system types will be explained. Videos of various types of manufacturing systems will be shown.

1. Read: *A Taxonomy of Process Types Note*.

Session 2, **September 4** – *UTD Professor Maya Balakrishnan will discuss Combining Design Thinking with Generative AI for New Product Development.*

Learning objectives for this session:
- **Understand the core principles and iterative stages of the Design Thinking process as a framework for bringing structured creativity to new product development.**
- **Develop practical skills in leveraging Generative AI tools to enhance various stages of the Design Thinking process, including user research, problem definition, ideation, and prototyping.**
- **Explore current day approaches to combining qualitative and quantitative data, including the application of LLMs for conjoint analysis in new product design.**

1. Read:
   - Bryce Booth, Jack Donohew, Chris Wlezien, and Winnie Wu, "Generative AI fuels Creative Physical Product Design but is no Magic Wand," QuantumBlack, AI, McKinsey (March 2024).
   - James Brand, Ayelet Israeli, and Donald Ngwe, "Using LLMs for Market Research," Harvard Business School Working Paper (July 2024).

2. Skim:
   - "Design Thinking Bootleg," Hasso Plattner Institute of Design at Stanford (2018). Download from https://dschool.stanford.edu/tools/design-thinking-bootleg

Session 3, **September 11** – *UTD Professor Ashwin Venkataraman will introduce Machine Learning.*

Learning objectives for this session:
- **Differentiate the main paradigms of machine learning—supervised, unsupervised, and reinforcement learning—using accessible real-world examples.**
- **Describe the key steps of a basic machine learning workflow, including data preparation, model training, and evaluation.**
- **Recognize the role of data literacy in AI applications, including identifying relevant data sources, assessing data quality, and understanding preprocessing needs.**

1. Read:
   - Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani, An Introduction to Statistical Learning, Springer, 2nd Edition, Chapters 1 and 2 (2021). Download from https://www.statlearning.com/
   - "Foundational Courses," Google Developers, Sections: "Introduction to ML" and "Problem Framing". Download from https://developers.google.com/machine-learning/foundational-courses
   - Tom Mitchell, Machine Learning, McGraw-Hill, Chapter 1 (1997). Download from https://www.cs.cmu.edu/~tom/files/MachineLearningTomMitchell.pdf
   - Michael Nielsen, Neural Networks and Deep Learning, Determination Press, Chapter 1 (2015). Download from http://neuralnetworksanddeeplearning.com/chap1.html

- Richard Sutton and Andrew Barto, Reinforcement Learning: An Introduction, MIT Press, 2nd Edition, Chapter 1 (2018)
  Download from http://incompleteideas.net/book/RLbook2020.pdf

2. Recommended readings after class:
   - Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani, An Introduction to Statistical Learning, Springer, 2nd Edition, Chapters 3, 4, 6, 8, and 12 (2021).
     Download from https://www.statlearning.com/
   - "Foundational Courses," Google Developers, Section: "Machine Learning Crash Course".
     Download from https://developers.google.com/machine-learning/foundational-courses

Session 4, **September 18** – *Job Shop Scheduling.*

Learning objectives for this session:
- **Master the key elements of scheduling both work and workers in job shops. These include sequencing, schedule evaluation, and personnel scheduling.**
- **Appreciate the impact of variety and variability on scheduling operations.**

1. Read Chapter 10, *Shop Floor Control*, pp. 343-348.
2. Prepare *Aerospace Maintenance, Inc*.
   a. Calculate the workload on each of the four repair stations (in hours per day) imposed by a daily receipt of one engine of each type (A, B, and C). Is the current capacity of the shop sufficient to service the orders that Jack Quirk has taken?
   b. Develop a schedule for June 27 and 28 that would have increased profits.
   c. Then, think about worker scheduling, in 8-hour shifts, allowing overtime and/or undertime.
   d. What is the key to profitable operations for Aerospace?
   WARNING: This assignment can be an unbounded time sink. I suggest that you spend no more than 3 hours on it. If you still have time, give some thought to the scheduling of workers for 8-hour shifts.

Session 5, **September 25** – *Professor Tom Schmitt, University of Washington, Seattle will discuss Digital and Quantum Steps towards Profit in Job-Shop Scheduling,.*

Learning objectives for this session:
- **Introduce key aspects of job shop sequencing-and-scheduling decisions.**
- **Define drivers of short-term profit in a job shop system.**
- **Discuss how to approach job-shop scheduling for profit using Quantum Computing.**

Concepts will be introduced that may be intimidating without appropriate introductions in class. Brief abstracts are provided below as required reading. Supplemental reading below is recommended as background for those interested in learning more after the session.

1. Read abstracts:
   - **Digital and Quantum Steps towards Profit in Job-Shop Scheduling,** Thomas Schmitt, Mahdi Mokhtarzadeh, and Kathryn E. Stecke
   - Sequencing-and-scheduling for profit is a challenging undertaking for managers of job-shop systems. The problem is very relevant in practice from small metal fabricators and auto repair shops to large aerospace machine shops. Regardless of size, most firms share the profit objective, and are generally make-to-order producers. As such, customers expect a projection of a due date before booking an order. Revenue minus incremental time-related expenses limit the amount possible to cover fixed costs. It is reasonable to expect that a job may be booked only if there is a marginal baseline for profit, although a firm may choose to be more discriminating. Materials for a booked job, which arrive too early, generate unnecessary carrying costs in-process until delivery. Early arrivals may also result in the early completion of the job, while the customer need not take delivery nor pay before the due date. A tardy job completion means a missed order due date, delayed payment from the customer, possible contractual penalties, and a loss of goodwill in the future. Incremental profit is achieved by minimizing the funds tied up while the jobs are in process.

- **Programming Quantum Computers: Essential Algorithms and Code Samples,** Eric Johnston, Nic Harrington, and Mercedes Gimeno-Segovia**.**

Introduction (excerpt from page 1; text is on library reserve)

"Whether you're an expert in software engineering, computer graphics, data science, or just a curious computerphile, this book is designed to show how the power of quantum computing might be relevant to you, by actually allowing you to start using it.

To facilitate this, the following chapters do not contain thorough explanations of quantum physics (the laws underlying quantum computing) or even quantum information theory (how those laws determine our abilities to process information). Instead, they present working examples providing insight into the capabilities of this exciting new technology. Most importantly, the code we present for these examples can be tweaked and adapted. This allows you to learn from them in the most effective way possible: by getting hands-on.

<In class, we will access the book's quantum simulator for a particular application: Schrödinger's Cat mind experiment.>

Along the way, core concepts are explained as they are used, and only insofar as they build an intuition for writing quantum programs.

Our humble hope is that interested readers might be able to wield these insights to apply and augment applications of quantum computing that physicists may not even have heard of. Admittedly, hoping to help spark a quantum revolution isn't that humble, but it's definitely exciting to be a pioneer."

2. Background reading:
   - Eric R. Johnston, Nic Harrigan, Mercedes Gimeno-Segovia, Programming Quantum Computers: Essential Algorithms and Code Samples, O'Reilly, Beijing (2019), on UTD Library Reserve.
   - Thomas Schmitt, Mahdi Mokhtarzadeh, Kathryn Stecke, "Digital and Quantum Steps towards Profit in Job-Shop Scheduling," WP (2025). Available upon request.
   - Chris Bernhardt, Quantum Computing for Everyone, MIT Press, Cambridge, Massachusetts (2019). Paperback available through Amazon.
   - Elias Combarro, Samuel Gonzalez-Castillo, A Practical Guide to Quantum Machine Learning and Quantum Optimization, Pact Publishing, Birmingham, UK (2023). Paperback available through Amazon.
   - Robert Sutor, Dancing with Qubits, Pact Publishing, Birmingham, UK, 2nd Edition (2024). Paperback available through Amazon.

Tom will be available Friday afternoon (1-5pm) in JSOM 2.611 to discuss aspects of Quantum Computing with anyone who stops by.

Session 6, **October 2** – *UTD Professor Yonas Tadesse will discuss Adaptive Manufacturing and Innovation in Robotics.*

Learning objectives for this session:
- **Understand adaptive systems with flexible grippers and controls, minimizing waste, and modifications in industrial assembly.**

1. Read:
   - Syed Imranuddin, Abhishek Singh, Menberu Shiferaw, Pradeep Saroj, Kathryn Stecke, and Yonas Tadesse, "Vision-Assisted 4D Printing of a Silicone Gripper with Integrated Sensors and High Energy Density Actuators," 4D Printing, forthcoming (2025).
   - Josie Hughes, Kieran Gilday, Luca Scimeca, Soham Garg, and Fumiya Iida, "Flexible, Adaptive Industrial Assembly: Driving Innovation Through Competition: Flexible Manufacturing," Intelligent Service Robotics, Vol. 13, pp. 169-178 (2020).
   - Gianni Stano, S M Al Islam Ovy, Jakob Ryan Edwards, Matteo Cianchetti, Gianluca Percoco, and Yonas

Tadesse, "One-shot Additive Manufacturing of Robotic Finger with Embedded Sensing and Actuation," International Journal of Advanced Manufacturing Technology, Vol. 124, Nos. 1-2, pp. 467-485 (2023).

- S M Al Islam Ovy, Gianni Stano, Gianluca Percoco, Matteo Cianchetti, and Yonas Tadesse, "Inexpensive Monolithic Additive Manufacturing of Silicone Structures for Bio-inspired Soft Robotic Systems," Engineering Research Express, Vol. 5, No. 1, p. 015016 (2023).

Session 7, **October 9** - *High Volume Discrete Manufacture*.

Learning objectives for this session:
- **Understand the concepts behind designing a production line to balance workloads, cycle time implications, and worker considerations.**

1. Prepare the questions in *Assembly Line Design*.

Session 8, **October 16** – *UTD Professor Ashim Bose and Dr. Vivek Saxena, CEO of FactoryTwin will discuss AI in Factories - Smart Factories, Some Case Studies, and Critical Success Factors.*

Learning objectives for this session:
- **Understand Smart Factory concepts with a focus on AI applications.**
- **Develop an understanding of the implementation considerations.**

1. Read:
   - "Adopting AI at Speed and Scale: The 4IR Push to Stay Competitive", By Henry Bristol, Enno de Boer, Dinu de Kroon, Rahul Shahani, and Federico Torti, McKinsey & Company (February 2024). Download and print from https://www.mckinsey.com/capabilities/operations/our-insights/adopting-ai-at-speed-and-scale-the-4ir-push-to-stay-competitive
   - "Discover How the Manufacturing Industry Is Using AI and Accelerated Computing" NVIDIA, from the "Use Cases" section Download from https://www.nvidia.com/en-us/industries/manufacturing/
2. Prepare:
   - Read the "Use Cases" and "Success Stories" from the NVIDIA reading. Pick your favorite case (company) from the cases you read or another industry case that you are familiar with and analyze it further.
   - Use your imagination and experience to brainstorm and suggest how AI or ML or … might be used to address any of the company's problems. You may work together on this if you like. You will be called on to present your ideas and possible solutions to the class.

Session 9, **October 23 – Midterm Exam.**

Session 10, **Friday, October 31** – *A tour of Texas Instruments RFAB Wafer Fab Plant in Dallas will be held. It is an integrated circuit manufacturing facility. It is the 15th largest clean room in the world. We'll tour the entire line, seeing the diffusion process, plasma etching, photolithography, chemical and mechanical polishing, and more. We'll talk with the Industrial Engineer who does the scheduling, and other operators. We can stay until our questions are answered*.

Monday, November 3 – *Your one-page paper summary is due.*

Session 11, **November 6** – *Seru Production Systems.*

Learning objectives for this session:
- **Learn about a new Japanese organizational and production system, *seru*.**
- **Observe why it is better than conventional systems (more flexible, more efficient, and more productive).**

1. Read:
   - Yong Yin et al., "Why and How *Seru* Production Systems Are Responsive and Efficient in Volatile Markets", Production and Operations Management, forthcoming, 2025.

Download and print from the POM journal
https://journals.sagepub.com/doi/10.1177/10591478251352632 .

- Yong Yin et al., "The Evolution of Production Systems from Industry 2.0 through Industry 4.0", International Journal of Production Research (January 2018).
  Download and print from https://www.tandfonline.com/doi/full/10.1080/00207543.2017.1403664 .
- Yong Yin et al., "Lessons from *Seru* Production on Manufacturing Competitively in a High Cost Environment," Journal of Operations Management (March 2017).
  Download and print from https://www.sciencedirect.com/science/article/pii/S0272696317300116 .
- ChenGuang Liu et al., "An Implementation Framework for *Seru* Production", International Transactions in Operational Research (January 2014).
  Download and print from http://onlinelibrary.wiley.com/doi/10.1111/itor.12014/full .
- K. E. Stecke et al., "*Seru*: The Organizational Extension of JIT for a Super-Talent Factory", International Journal of Strategic Decision Sciences (March 2012).
- Yong Yin et al., "The Evolution of *Seru* Production Systems Throughout Canon", Operations Management Education Review (December 2008).

2. Class introduction: What are your experiences and interests in AI and machine learning? What aspects are you familiar with?

Session 12, **November 13** – *Introduction to Flexible Automation.*

Learning objectives for this session:
- **Develop an understanding of what an automated, flexible machining system is and what its capabilities are.**
- **Become familiar with the basic vocabulary of flexible automation.**

1. Read:
   - "Major Detroit Automotive Manufacturer's Conveyor Problem Leads to a Case of the Munchies," Tooling & Production (July 2016).
   - "CNC Mini Mills Enable Medical Manufacturer to Produce an Artificial Disc that Could Revolutionize Treatment of Back Injuries," Tooling & Production (June 2012).
   - Martin Piszczalski, "Strategies for Spending Millions," Managing Automation (August 1987).

2. Flexible manufacturing systems (FMSs) and their components and benefits will be defined. Differences from conventional systems will be explained. Many examples of existing systems from various countries will be described, to demonstrate the wide variety of systems (and problems).

3. A film featuring several U.S. FMSs will be shown.

Session 13, **November 20** – *Group Paper Presentations.*

December 4 – *Papers due.*