OPRE 6340: Flexible Manufacturing Strategies, Fall 2015
Professor Kathryn E. Stecke
Course Pack

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"A Flexible Approach to Part Type Selection in Flexible Flow Systems Using Part Mix Ratios," International Journal of Production Research (2/91)

"Big Brother is Watching," Modern Applications News (4/09)

"Moving, Machining, Testing Parts 24 Hours a Day," Modern Applications News (3/04)

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"Sequencing and Scheduling in Robotic Cells: Recent Developments" (2005)

"Design, Planning, Scheduling, and Control Problems of Flexible Manufacturing Systems," Annals of Operations Research (1985)

"FMS Design and Operating Problems and Solutions," Proceedings of the Second Intelligent FA Symposium, Osaka (7/89)

"Interior Evaluation Goes Robotic," Ward's Auto World (3/10)

"C-3PO's Great Grandfather," Modern Applications News (6/08)

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"Manufacturing in the 21st Century," Managing Automation (10/99)

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OPRE 6340: Flexible Manufacturing Strategies **Fall 2015 (Thursdays, 4:00-6:45 PM)**

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Course Synopsis

U.S. manufacturing companies are continuing to be threatened by radical changes in the competitiveness within their industries. Automated manufacturing is viewed as one means of helping to regain or maintain international competitiveness. The use of automation in manufacturing (machining, fabrication, assembly, etc.) is continually increasing. A flexible manufacturing system provides just-in-time performance and can allow competition along the dimensions of time, service, quality, delivery, flexibility, and sometimes cost.

The course will be interspersed with lectures, cases, and short films on the various types of automation, problems that need to be addressed, and solution methods. Examples of many international systems (from Italy, Germany, Japan, Czechoslovakia, England, U.S., and others) will be discussed to show the wide variety of system designs (and problems). Strategic as well as economic justification issues will be addressed.

A special half-day session will be a tour of the fully automated flexible systems at the Texas Instruments DM0S6 Wafer Fab Plant on **Friday, November 6** to see first-hand what unique operational problems (and opportunities) exist. 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. Detailed discussions with the system managers and operators can take place.

Part of the course will focus on operational issues and problems, and will include case analyses to demonstrate the problems actually faced. We will 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. The cases detail several Japanese and American flexible manufacturing systems. We also will learn from the readings, lectures, tours, and group presentations on particular topics.

General Information

Because of the relative newness of the technologies, there isn't yet an appropriate textbook available. Hence, the materials will come solely from the cases and readings in the Course Pack and in some handouts during the semester. I am in my office most afternoons and evenings. Please stop by (**SOM 2.422**), call me (**972-883-4781**), or leave me a note.

In order to emphasize the role of the general manager in operations in a modern automated manufacturing environment, cases will be used throughout the course. 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 operating 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 which interact with one another, and any proposal must consider system-wide consequences. Operating managers are paid for making decisions and not for performing analyses; however, studies of operating managers indicate that those 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. Further develop a managerial point of view--a capacity for analyzing operating problems in technologically advanced systems on a functional, business unit, and company-wide basis.
2. Integrate the knowledge gained in previous business courses and to extend that into the area of contemporary automation operations 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.
4. Introduce the details concerning the variety of types of flexible automation, including flexible manufacturing systems, integrated circuit fabrication and assembly, and robotics, with an emphasis on how these differ from conventional manufacturing.
5. Understand the strategic benefits as well as the economic justification issues.
6. Learn about the design, planning, scheduling, control, and integration problems that are unique to automation.
7. Understand the benefits and problems of many types of flexibility.

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, such as system integration issues, tool management, flexible assembly, flexibility issues, and automation software issues, for example. The main purposes of this group project are to let you explore in some detail a topic concerning flexible automation 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, October 19**. 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 **December 3** and the final paper due on **December 8**. Accompanying each written report should be a set of photocopies of the overheads used in the oral presentation. Preparation and distribution of all materials (e.g., photocopies of overheads) 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 **October 19** at the latest.

The final grade is determined by an average of the midterm (33 1/3%), final paper and presentation (33 1/3%), and class participation (33 1/3%). 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. Invariably, given the complexities of the real world, there is no answer, as such. 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 also 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 not useful for our case discussions. I know that some students like to take notes in class on their computers. Every term, some students come to me to complain 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 in not allowed. Cell phones should always be turned off. If you must send a text, please leave the room.

Attendance

There are occasional legitimate conflicts that prevent a student from completely preparing a given case, 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, again, please inform me so that I understand your situation. By enrolling in this course, you are, in effect, agreeing to do your best to attend and contribute to the group learning experience.

Reserve

The following book is on reserve in McDermott Library.

- Horst Tempelmeier and Heinrich Kuhn, Flexible Manufacturing Systems: Decision Support for Design and Operation, John Wiley & Sons, NY (1993).

Course Outline

Session 1, **August 27** - *Course Introduction.*

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:
   - "CNC Mini Mills Enable Medical Manufacturer to Produce an Artificial Disc that Could Revolutionize Treatment of Back Injuries," Tooling & Production (June 2012).
   - "Not Your Father's Space Shuttle," Modern Applications News (March 2007).
   - "European Fab Shops Profit with Automation," Modern Applications News (July 2006).
   - "CAM Cuts Errors 80%, Programming Time 66%," Modern Applications News (May 2005).
   - "Designing with CAD, Artist Sculpts Choppers," Modern Applications News (May 2005).
   - "CAD, CAM, or CAD/CAM? Is It For Your Shop?," Modern Applications News (April 2004).
   - "Texas Precision Manufacturing on an Ego Tripp," Winner's Circle (June 2001).
   - "James F. Manji, "Microbrewery Draws Big Benefits from PLC Control," Managing Automation (April 1998).

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, in order to demonstrate the wide variety of systems (and problems).

Session 2, **September 3**- *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:
   - "Small Fixes Have Big Green Pay-offs," Modern Applications News (April 2009).
   - "Getting by With a Little Help from Friends," Modern Applications News (April 2008).
   - "Universal Storage System Automates Fab Shops," Modern Applications News (May 2005).
   - "Mobile Parts Hospital Uses Quick Change Tooling," Production Technology News (Feb 2004).
   - "Computer Numerical Controls," Modern Applications News (July 2003).
   - "FMS Turns Work Cells Into Manufacturing High Flyers," Modern Applications News (December 1999).
   - Martin Piszczalski, "Strategies for Spending Millions," Managing Automation (August 1987).
   - Paul Kinnucan, "Flexible Systems Invade the Factory," High Technology (July 1983).

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

Session 3, **September 10** - *Strategic Considerations of Flexibility.*

Learning objectives for this session:
- **Understand the risks involved when innovating with new technologies.**
- **Recognize the organizational support that is needed to support technological change.**
- **Understand the significant advantages from flexible automation and the value of flexibility.**
- **Appreciate the newer strategies in selling and using FMSs.**

1.Read:
   - "High-speed Machining Cells Allowed Boeing to Create Higher Quality Parts 30% Faster Than Ever Before," Tooling and Production (October 2013).
   - "A Plastic Dream Machine," Business Week (June 2005).

- "Breakthrough 5-Axis Technology Dramatically Improves Production of Eurofighter Large Parts," WolfTracks (2001).
- "LTV Aerospace to Remain Independent Under Lockheed," Aviation Week and Space Technology (February 10, 1992).

2. Prepare Vought Aero Products: Factory of the Future.
   a. What were the major barriers to successful introduction and implementation of the flexible machining cell (FMC)? How were these barriers overcome? Why did Vought succeed where others failed? What were their particular operating problems? What did the company learn about managing advanced and automated manufacturing projects from the FMC?
   b. What is the role of the Industrial Modernization (IMOD) group at Vought? What is the role of the Manufacturing Development and Support (MD&S) group? Are both groups necessary?
   c. Should Vought build the Integrated Machining System (IMS)? Why or why not? What are the risks of each project? How do its risks and benefits compare with those of the Flexible Composites Center (FCC)?

Session 4, **September 17** - *Introduction of New Technology, Strategic Automation Acquisition,* and *Other Types of Flexible Automation*.

Learning objective for this session:
- **Become familiar with the problems and typical pitfalls in first evaluating, then implementing, a new technology**.

1. Read:
   - Bharat K. Kaku, "Fitting Flexible Manufacturing Systems to the Task," Industrial Engineering, Vol. 26, No. 11 (November 1994).
   - Robert S. Kaplan, "Must CIM be Justified by Faith Alone?," Harvard Business Review, Vol. 64, No. 2 (March-April, 1986).

2. Prepare Chaircraft (B).
   a. Evaluate the key management decisions made concerning the Hancock Cutter:
      -Decision to purchase the automated equipment;
      -Implementation decisions.
   b. What should Mr. Mitchell do now?
   c. What are the long-run implications of the Hancock Cutter experience for Chaircraft?

3. Class introduction: What are your experiences and interests in flexible automation? What types of automation are you familiar with?

4. Read:
   - "Mass Customization at Hewlett-Packard: The Power of Postponement," HBR, (Jan-Feb 1997).

Session 5, **September 24** – *Professor Majid Minary will present new research on 3-dimension (3D) microscale and nanoscale manufacturing technologies and their comparative advantages.*

Learning objectives for this session:
- **Learn the current technologies for manufacturing small things in 3D.**
- **Understand advantages and disadvantages of each technology.**

Read:
- "A Review on 3D Micro-additive Manufacturing Technologies," International Journal of Advanced Manufacturing Technology (2013).
- "Meniscus-Confined Three-Dimensional Electrodeposition for Direct Writing of Wire Bonds," Science (July 2010).
- "First 3D Printing Database Allows You to Search for Additive Manufacturing Machines and Materials All in One Place," Tooling & Production (March 2015).
- "Senvol Database Now Includes Additive Manufacturing Pricing Information" (April 2015).

Session 6, **October 1** - *Manufacturing Flexibility/Seru Production Systems.*

Learning objectives for this session:
- **Discover how a lot of benefits can be obtained from a little flexibility.**
- **Explore how flexibility can help in risk mitigation.**
- **Learn about the state-of-the-art research and practices in flexibility and risk mitigation.**
- **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:
   - W.C. Jordan and S.C. Graves, "Principles on the Benefits of Manufacturing Process Flexibility," Management Science, pp. 577-587 (April 1995).
   - Jim Browne, Didier Dubois, Keith Rathmill, Suresh P. Sethi, and Kathryn E. Stecke, "Classification of Flexible Manufacturing Systems," The FMS Magazine, pp. 114-117 (April 1984).
   - Andrea Krasa Sethi and Suresh P. Sethi, "Flexibility in Manufacturing: A Survey," International Journal of Flexible Manufacturing Systems, (July 1990).
   - Jerry Flint, "More Models, Fewer Platforms," Ward's Auto World (April 2006).

2. A film will show the new machine tools of Fritz Werner Werkzeugmaschinen AG, Berlin and demonstrate their newer strategic shift into the high-volume market.

3. Read:
   - ChenGuang Liu et al., "An Implementation Framework for *Seru* Production", International Transactions in Operational Research (January 2014).
   - 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).
   - "Radical New Way to Build Vehicles," Ward's Auto World (September 2011).
   - "Comau Sells Smart Assembly," Ward's Auto World (February 2010).

Session 7, **October 8** - *Quality Function Deployment in Flexible Manufacturing: Guest speaker, Glenn Mazur, President, Japan Business Consultants, Ltd. and Director of the QFD Institute.*

Learning objectives for this session:
- **See how customer value can be connected to manufacturing setup requirements.**
- **Understand that flexible manufacturing delivers value because it allows a company to vary its products in accordance to customer needs.**

Read:
"Jurassic QFD: Integrating Service and Product Quality Function Deployment," Eleventh Symposium on Quality Function Deployment, Novi, Michigan (June 1999).

Session 8, **October 15 - Midterm Exam**.

Monday, October 19 -*The one-page paper summary is due.*

Session 9, **October 22** - *Flexible Manufacturing Capacity Expansion Decisions, Implementation Plans, Technological Adoption Decisions, and Economic Justification.*

Learning objectives for this session:
- **Understand the capacity implications of new technology acquisition decisions over time.**
- **Develop an understanding of the cost calculations and capacity analyses for various alternatives.**

1. Read:
   - "Get the Most from CNC Automation Investments," Modern Applications News (February 2007).
   - "An Integrated Model for Part-Operation Allocation and Investments in CNC Technology," International Journal of Production Economics (December 2002).
   - Robin Cooper and Robert S. Kaplan, "The Promise-and Peril-of Integrated Cost Systems," Harvard Business Review (July-August 1998).

2. Prepare Baker Precision Instruments, Inc.
   a. What could be done in the short term? How would you deal with the immediate capacity crunch? How would you phase in any new FMSs?
   b. How much capacity should be acquired and when? Develop a capacity expansion plan that takes into account demand projections from 1996 through 1999 so as to achieve the objectives of low cost, fast, reliable delivery, and good quality.
   c. How did you consider the setups between families and within families?
   d. What kind of capacity would you recommend Baker buy? In the long run, what are the pros and cons of both FMS types? Take into account both qualitative and quantitative factors.

Session 10, **October 29** - *An Integrated, Completely Automated, Japanese Flexible Manufacturing Factory*.

Learning objectives for this session:
- **Understand the difficulties in effectively using and operating such highly automated, integrated systems.**
- **Develop an awareness of a new paradigm useful in measuring plant effectiveness.**

1. Read:
   - K.E. Stecke, "Procedures to Determine Part Mix Ratios for Independent Demands in FMSs" IEEE Transactions on Engineering Management (November 1992).
   - K.E. Stecke and Ilyong Kim, "A Flexible Approach to Part Type Selection in Flexible Flow Systems Using Part Mix Ratios," International Journal of Production Research (January - February 1991)

2. Read:
   - "Big Brother is Watching," Modern Applications News (April 2009).
   - "Moving, Machining, Testing Parts 24 Hours a Day," Modern Applications News (March 2004).
   - Raymond Chalmers, "A Journey to Japan," Manufacturing Engineering, pp. 80-85 (September 1998).
   - "Manufacturer's "Star Wars" Approach Boosts Productivity to Near 90%," Modern Applications News (August 2000).
   - "Manufacturer Uses Advanced Processes," Metalworking Digest (September 2000).
   - "Mazak's Brian Papke Discusses Machine Tools in the 21st Century," Modern Applications News (September 2000).

3. Prepare Yamazaki Mazak (A).
   a. How much of the organizational structure and processes are transferrable from Japan to the factory in the United Kingdom?
   b. Under what conditions would Yamazaki want to consider adopting automated, centralized controls of its production process? What are the key factors that would drive such a decision?
   c. How can Yamazaki improve its capacity utilization? Where are the biggest problems? What are some potential solutions?
   d. How can an FMS Plant Manager measure the efficiency of the plant?

Session 11, **Friday, November 6** - *A tour of Texas Instruments DM0S6 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.*

Session 12, **November 12** - *Professor Milind Dawande will present new research on better sequencing and scheduling of robotic cells.*

Learning objectives for this session:

- **Become familiar with the various types of robotic cells, characterized by robot type, robot travel time, types of parts processed, and use of parallel machines.**
- **Understand the concepts of cyclic solutions for improved productivity of robotic cells in repetitive manufacturing.**
- **Learn algorithms to find optimal cyclic solutions for various types of robotic cells.**
- **Hear about exciting open research issues.**

1. Read:
   - S.P. Sethi et al., "Sequencing of Parts and Robot Moves in a Robotic Cell," International Journal of Flexible Manufacturing Systems, Vol. 4 (1992).
   - M. Dawande et al.," Sequencing and Scheduling in Robotics Cells: Recent Developments," Journal of Scheduling (2005).

2. Read:
   - K.E. Stecke, "Design, Planning, Scheduling, and Control Problems of Flexible Manufacturing Systems," Annals of Operations Research, Vol. 3 (1985).
   - Kathryn E. Stecke, "FMS Design and Operating Problems and Solutions," Proceedings of the Second Intelligent FA Symposium, Osaka, Japan (July 19-21, 1989).

3. A film featuring other types of automation, i.e., robotics applications, will be shown.

4. Read:
   - "Interior Evaluation Goes Robotic," Ward's Auto World (March 2010)
   - "C-3PO's Great Grandfather," Modern Applications News (June 2008).
   - "Robot Adds Horsepower to Motorcycle Aftermarket Shop," Modern Applications News (February 2007).
   - "Robots Set Pace at Auto Supplier," Modern Applications News (December 2005).
   - David Brousell, "Here Come the Superheavyweights," Managing Automation (July 2002).

Session 13, **November 19** - *The Future of Flexible Automation: Reconfigurable Manufacturing Systems.*

Learning objectives for this session:

- **Learn about several approaches to operate an FMS over time, where each approach is appropriate under different circumstances.**
- **Learn about the next generation in flexible manufacturing, reconfigurable manufacturing.**

1. We'll discuss the future developments of flexibility in manufacturing.

2. Read:
   - Erin Callaway, "Manufacturing in the 21st Century," Managing Automation (October 1999).
   - Shamel Rushwin, "Manufacturing Strategies in the 21st Century," Japan-US Symposium on Flexible Automation (July 2000).

3. FMS Video

Session 14, **December 3** - *Group Paper Presentations.*

Tuesday, December 8 - *Papers due.*