Chapter 11

Industry Applications of Production Flow Analysis by IE Students

IE Tools ought to Replace the Lean Tools

There is consensus in the Lean community that the Lean tools alone are never going to sustain a Lean implementation. ***Nothing*** can compensate for lack of support from upper management! Still, compared to the many manual and computer-aided tools that IEs use, the manual pencil-and-paper Lean tools are incapable of solving complex problems. So, it is **not** just the lack of support from upper management that has prevented industry from reaping the full benefits from implementing Lean. It is also the over-reliance on simple manual tools and the rejection of far more powerful tools because "Toyota does not use them".

Replacing the IE in Mainstream Textbooks with "Toyota IE"

While the Lean tools have their shortcomings, the IE that is underlying them is superior to the archaic IE that is taught in our textbooks. That was the reason I sought to complement the mainstream textbooks I was using for IE courses on Facilities Planning and Production Control. These textbooks contain no examples of how the IE concepts, methods and tools they teach were actually put to work in the real world! Since the books on Lean were my only "look into the mind of Toyota", I started blending the "Textbook IE" with the relevant "Toyota IE". In Appendix 1, I compare the "Textbook IE" that is taught in academia and the "Toyota IE" that industry uses.

Courses that Merged the Classroom and the Factory Floor

Being a full-time IE faculty, I was unable to work full-time in industry to learn how practitioners were implementing Lean. For the same reason, I was unable to personally spearhead the adoption of my advanced research on JobshopLean. But the same could not be said for my students, both undergraduate and graduate! They were in a better position to work in industry and assess whether what I taught them in my classes worked in practice. So, I revamped all the courses I taught by ***blending*** Lean, IE and OR (Operations Research) as follows:

1. In each of the undergraduate courses, I replaced the outdated Industrial Engineering with the appropriate "Toyota IE" and related Lean tool/s.
2. The graduate course was devoted to JobshopLean.
3. If there was an Operations Research model or computer algorithm to computerize the pencil-and-paper Lean tool, I would teach that too.
4. All four courses had a mandatory industry project that required students to work in teams at a local company that had agreed to host one or more teams.

With every industry project that a team of students did in any course, I got to learn whether what I was teaching was applicable in industry.

Programs for an IE Department to Engage with Industry[1]

The course projects were just one way in which the students and I learned if the ***blend*** of Lean, IE and OR (Operations Research) that I was teaching them worked in practice. In addition to the

[1] If you would be interested in receiving an electronic copy of a report that provides details about the scope, deliverables and cost for each of the programs in the Industry Outreach and Engagement portfolio of an IE department, please email me at ShahrukhIrani1023@yahoo.com.

courses, I leveraged all of the co-curricular and extra-curricular programs that a strong IE department, such as the one at The Ohio State University, gives its students and faculty to engage with industry:

- Independent Study Projects
- Senior Capstone Design Projects
- Undergraduate Honors Theses
- Masters Non-Thesis Projects
- Masters Theses
- Internships
- Sponsored Research Grants
- Consulting
- Workshops
- Presentations to industry attendees at the Annual JobshopLean Conference

All of the above programs allowed me to work with a large number of students who applied what I taught them in my courses in industry projects that had been assigned to them. Each project yielded a close-out report or presentation that helped to assess if the **blend** of IE, Lean and OR was theory that worked in practice.

Presentations and Reports for Student Projects

This chapter showcases presentations and reports that were prepared by IE students for the projects they did in industry. Some of the projects were done for one or more of the core courses on Industrial Engineering that I taught them. Others were done as internships I arranged for them at companies interested in implementing JobshopLean. Table 1 gives details about each project that was done by different students for different courses that I taught at The Ohio State University.

Table 1 Details about Projects Done by Different Students

Sponsor Company	Student/s who did the Project	Brief Description of the Project
Bula Forge & Machine Inc.	Bryan Wang	This presentation titled *Results and Experiences from Implementing the Quick-Start Approach to JobshopLean in a Custom Forge Shop* describes the work that Bryan did during his internship.
Enginetics Aerospace	Po-Hua Tseng	This Masters Non-Thesis Report titled *Designing a Flexible and Lean Manufacturing Facility using a Large Representative Sample of Different Parts* describes the work that Po-Hua did during his internship at a commercial and defense aerospace manufacturer.
Guardian Automotive	Alwyn Aliwarga	This presentation titled *CSM/Lean* (CSM = Common Sense Manufacturing) describes the work that Alwyn did during his internship to complement and enhance a company's ongoing implementation of Lean with relevant Industrial Engineering and JobshopLean practices.
Hirschvogel Inc.	Alwyn Aliwarga	This presentation titled *Learning To See and Seeing The Whole using Value Network Mapping* describes the work that Alwyn did at a Tier 1 forging facility for his Master of Science degree in IE. He demonstrated that a Lean implementation in a high-mix high-volume facility can be done without using Value Stream Mapping. The Masters Non-Thesis report that Alwyn wrote based on this work is included.

Horton Emergency Vehicles	Alwyn Aliwarga	This presentation titled *Project Review: Back-end Facility Design* describes the work that Alwyn during his internship to streamline the flow of a large variety of parts that were produced in a Fabrication Shop. This shop was the "back end" of a single assembly line that built a variety of ambulances. It was ideally suited for the implementation of JobshopLean because it had to produce different kits of parts that had to be delivered per a timed schedule to different stations in the assembly line.
Maritime Castings Repair Facility	Dan Gallo	This presentation titled *Implementing Job Shop Lean in a Casting Repair Facility* describes the work that Dan did during his internship to implement JobshopLean in a captive machine shop adjacent to a foundry owned by the same company. The Final Report that was submitted to the agency that funded our work is included.
OSU (Ohio State University) Medical Center	Nirikshina Gowd	This Masters Non-Thesis Report titled *Equipment Flow Analysis (EFA) and Application of Lean Principles in Hospital Operations* describes the work that Nirikshina did for her Master of Science degree in IE. She used the method of Production Flow Analysis to analyze the availability and utilization of patient transport equipment.in a large hospital complex subject to factors such as the layout of the Medical Center, volumes of patient flows between and within buildings, communications between dispatchers and patient transporters, etc.
Trafficware	Ashwin Justus Amol Musale Azhar Nawaz	This Independent Study Project Report titled *How to Speed Product Flow in the 980X Controllers Cell* describes the work that Ashwin, Amole and Azhar did during their co-curricular project to get hands-on Industrial Engineering experience. They supported one of my consulting projects to improve throughput in a manual assembly cell.
Trinity Forge	Nathan Huffmann John Schott	This presentation titled *Process Analysis to Improve Tooling Management in a Custom Forge Shop* describes the work that Nathan and John did during their internship in a custom forge shop. Their project focused on the preparation, transportation, post-use put-away and storage of forging dies and related tooling that had to be sent to different forging presses in the forge shop. In the words of the VP of Trinity Forge, "What an eye opener this Lean Tooling project has been. This project will affect tooling movement (in our shop) for years to come."
UniPrint	Natalie Dexter Emilie Hehl Colleen Lorencen	This report titled *An IE Student's Guidebook for Facility Assessment and Redesign using Jobshop Lean Best Practices* describes the work that Natalie, Emilie and Colleeen did to apply what they were taught in the two courses on *Facility Design* and *Production Control and Scheduling* that I taught in the same quarter. Quoting from Page 1 of their guidebook, "This document has been created to serve as a guidebook that will demonstrate how to successfully evaluate a facility through the use of Lean Manufacturing, Theory Of Constraints and other Industrial Engineering techniques."[2]
Xunlight Corporation	Alwyn Aliwarga	This presentation titled *Xunlight Operational Improvements: Facility Design* describes the work that Alwyn did during his internship in the Module Assembly area of a low-volume hi-tech start-up assembly facility.

Syllabi for the Courses

[2] After the quarter ended, the team volunteered to continue working with UniPrint to implement some of their recommendations.

Appendix 2 is an abridged version of the syllabus for the undergraduate course on *Process Analysis and Improvement* that I used to teach at The Ohio State University.

Appendix 3 is an abridged version of the syllabus for the undergraduate course on *Facility Layout* that I used to teach at The Ohio State University.

Appendix 4 is an abridged version of the syllabus for the undergraduate course on *Production Control and Scheduling* that I used to teach at The Ohio State University.

Appendix 5 is an abridged version of the syllabus for the graduate course on *JobshopLean* that I used to teach at The Ohio State University.

Please email me at ShahrukhIrani1023@yahoo.com if you would like to receive the complete syllabus for any of these courses.

A Tribute to my Students

I feel privileged to have taught and mentored the students whose reports and presentations have been included in this chapter. They put into practice what they had learned in class in such impressive fashion! The work they did is clear evidence of their own abilities and work ethic. I pray that all of them are successful and happy in their professional lives as Industrial Engineers.

Appendix 1

A Comparison of "Textbook IE" and "Toyota IE"

IE taught in textbooks	IE that I attribute to Toyota
• OR model is taught without explanation of what it takes to obtain the values for coefficients, upper and lower bounds, assumptions that may compromise the feasibility of implementation in industry, etc. • OR model makes assumptions and simplifications in the actual problem in order to realize a solution • OR model taught out of an academic textbook with no case studies to demonstrate industrial application of the model	• Projects that are done are those which company leadership understands and supports ("I'd rather do what I understand instead of what is too complicated and tough to implement") • As the developer of the solution/s, be sure to work side-by-side with employees who will be affected by the solution/s and ensure that they accept/implement the solution/s • It is okay to solve many small problems for which radical changes will not be necessary (neither an OR model)
Students are recommended to go to the College of Business for courses on Lean Leadership, Change Management, Culture Change, Workforce Motivation, etc.	• Know, or at least be acutely aware of, the importance of soft skills to effect change • Gain acceptance for one's ideas by building trust among employees that changes will not be harmful to them
• Learning happens almost exclusively in the classroom • Industry relevance of course material is primarily delivered with, for example, Harvard Business Review case studies • Industry projects in a course are viewed by students as "being too much work" • Co-ops and internships never have faculty engaged/partnered with the students • Capstone Design project, which is done at the end of the program of study, is usually the only time when learning occurs by immersion in industry	• "Stand on the X" for hours and watch work being done in the area where improvement is sought • Go talk to the employees to find out the problem's and their root causes on one's own --- See for yourself, learn for yourself • Work, and problems related with doing it, is best learned by doing it oneself
• Industry experience is not a requirement to teach IE courses • An engineering degree, let alone an IE degree, is not a requirement to teach IE courses • Sabbatical leave is not taken to gain industry experience	• Have the ability to work side-by-side with line workers and supervisors is essential • Engage with employees and encourage them to implement their ideas for improving the product they make, the equipment and tools they use, their workplaces, etc.
Course on Methods Analysis and Time Studies	
Methods Analysis is an afterthought in the core curriculum	• Any and all work can be decomposed into value-added, non-value added and necessary-but-non-value-added elements • Cost reductions that do not eliminate employees can be achieved simply by eliminating the Seven Types of Waste in the entire organization • The ability/skill to recognize the Seven Types of Waste is best learned from co-ops, internships and industry projects (at least

	never solely in a classroom)
Methods Analysis is done using archaic methods such as Flow Process Charts and Man-Machine Charts	Methods Analysis is done using more effective tools such as Value Stream Mapping, Standard Work Instructions and 3P (Production Preparation Process)
Course on Facilities Planning	
The leading textbooks do not have a single case study to demonstrate that subject matter in them has practical application	• Teach the OR underlying the manual Lean tools such as Value Stream Mapping, Spaghetti Diagrams, U-shaped cells, Water Striders, etc. • Term project requires that students do a team-based project in industry where they must demonstrate how they applied what is being taught every week
Course on Production Planning and Control	
The Economic Order Quantity (EOQ) model for inventory control is taught as a calculus problem	• Utilize setup reduction to make setup time (and cost) insignificant when making lot size decisions • Make To Order policy --- Do not batch produce assuming significant setup time and put excess inventory in stock
The Economic Production Quantity (EPQ) model for inventory control is taught as a calculus problem	The Economic Production Quantity (EPQ) model for inventory control provides the science underlying the ultimate goal of Single Piece Flow in any work environment
Material Requirements Planning	• Generate a level-loaded mixed model production plan • Design flexible lines with minimal setup change times to adapt to product mix changes
• Heuristic scheduling of job shops with zero transfer delays • Finite Capacity Scheduling • ERP • MES	• Reduce the large job shop to a network of smaller autonomous work cells • Utilize rough-cut shop loading strategies such as Drum-Buffer-Rope, 3-bin Kanban locations, Bottleneck Loading, etc. • Have morning huddles with employees to assign job priorities • Allow fire-fighting and expediting as long as the customer is happy • Customers do tolerate tardiness, suppliers will dictate delivery dates, machines will fail, employees will fall sick --- Yet, it is amazing what good supervisors and cooperative employees can do when they are asked to "move heaven and earth"
Every possible OR optimization approach – TSP, Queuing Theory, Mixed Integer Programming – has been used to schedule and sequence jobs on the single capacity-constrained machine	• Show how setup reduction and product variety reduction help to minimize the need for setup-dependent sequencing of jobs
• Lot sizes are based on queuing theory (which implicitly assumes batch production) • Schedules are generated in a back office away from the shopfloor	• Design the layout to place consecutive pairs of workcenters in close proximity with each other • Production rate of "supplier workcenter" is controlled by "customer workcenter" using

	physical or electronic signals (kanbans) • Visual monitoring of buffer inventories between workcenters • "Go See" scheduling to replenish on-hand inventories of different products (like when the cooks in the kitchen come out to replenish food in various dishes at a Chinese buffet)
• Mfg. Processes course is absent from the core curriculum • Mfg. courses offered in other departments do not cover the topics of interest to IE's	• Add the Mfg. Processes course back into the curriculum • Add a second course – Mfg. Eng. – that teaches IE-related aspects of Lean such as standardization, setup reduction, error-proofing, autonomation, Total Productive Maintenance, Lean automation, right-sized equipment, 3P, etc.
Powerpoint presentations are the de facto mechanism for reporting on any project	• A3 Report • Powerpoint slides are presented only if and when more details are needed

Appendix 2

Syllabus for Undergraduate Course on Process Analysis and Improvement

ISE540 Production Systems Design
Spring 2012
Call Number: 11110
Instructor: Shahrukh A. Irani
Instructor's Contact Information: 688-4685, irani.4@osu.edu
Instructor's URL: http://ise.osu.edu/biosketch_SIrani.cfm
Course Audits: None
Course Prerequisites: ISE500
Class Meeting Time: 8:30 a.m. – 10:18 a.m. Tue & Thur
Classroom: Room 120, Caldwell Lab
Number of Credits: 4

Course Objectives: This course will provide the knowledge and develop the skills to use practical concepts, tools and software for Production Systems Design (PSD). Specific learning objectives for this course are:

- To learn *traditional* IE methods for PSD[3]
- To learn *non-traditional* methods for PSD that were pioneered at Toyota (aka LEAN)[4]
- To learn *non-traditional* methods for PSD that were pioneered at Motorola (aka SIX SIGMA)[5]
- To learn *non-traditional* methods for Production Systems Design (PSD) that were pioneered by Dr. Eliyahu Goldratt (aka THEORY OF CONSTRAINTS)[6]
- To learn OR models and software for PSD
- To learn the use of Value Stream Mapping (VSM) for process improvement and design of assembly lines, including repetitive low-mix high-volume work systems in the health care, service and IT sectors

ABET Program Outcomes that are addressed by this Course:

- **ABET Program Outcome 3(a):** An ability to apply knowledge of mathematics, science and engineering
- **ABET Program Outcome 3(b):** An ability to design and conduct experiments, as well as to analyze and interpret data
- **ABET Program Outcome 3(c):** An ability to design a system, component or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
- **ABET Program Outcome 3(d):** An ability to function on multidisciplinary teams
- **ABET Program Outcome 3(f):** An understanding of professional and ethical responsibility
- **ABET Program Outcome 3(g):** An ability to communicate effectively
- **ABET Program Outcome 3(h):** The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
- **ABET Program Outcome 3(j):** A knowledge of contemporary issues
- **ABET Program Outcome 3(k):** An ability to use the techniques, skills and modern engineering tools necessary for engineering practice

ABET Program Outcomes that <u>may not</u> be addressed by this Course:

- **ABET Program Outcome 3(e):** An ability to identify, formulate and solve engineering problems
- **ABET Program Outcome 3(i):** A recognition of the need for, and an ability to engage in life-long learning

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[3] **Examples:** Operations Analysis, Time and Motion Study, Work Measurement, Facility Layout, Material Handling, Production Scheduling
[4] **Examples:** Setup Reduction, 5S, Visual Management, Single-Piece Flow, Work Cells, Pull Scheduling, Visual Inventory Control using Kanbans, Mistake-Proofing, Lean Automation, Right-Sized Equipment
[5] **Examples:** Root Cause Analysis, Tree Diagrams, Affinity Diagrams
[6] **Examples:** POOGI (Process of Ongoing Improvement), Drum-Buffer-Rope Scheduling

Textbooks:

- Groover, M. P. (2007). *Work Systems: The Methods, Measurement, and Management of Work*. Upper Saddle River, NJ: Pearson Education Inc. ISBN 0-13-140650-7.
- Rother, M. & Shook, J. (2009). *Learning To See: Value Stream Mapping To Create Value And Eliminate Muda*. Brookline, MA: The Lean Enterprise Institute. ISBN 0-9667843-0-8.[7]

Lecture Materials: Prior to every class, please check Carmen to see if I have added any lecture materials for that day. **If I have done so**, then please bring those materials (or your laptop) to class. If necessary, I will complement these notes posted online with in-class handouts.

Course Software: STORM is an (OR) Operations Research package that contains a wide range of basic quantitative models taught in many IE courses. I use STORM for the sake of convenience and familiarity because it is very easy to learn to use this simple OR package by self-study. However, I encourage you to meet me during office hours, preferably in groups, to learn the use of this package. In addition, I will use it during some lectures to demonstrate how computer-aided methods for PSD trump manual methods like Value Stream Mapping. For further information on STORM, please contact Prof. Kamlesh Mathur, STORM SOFTWARE, 23811 Chagrin Blvd., Suite LL60, Beachwood, OH 44122. Phone: (216) 464-1209, Email: kxm6@case.edu.

Interested in developing IE software like STORM? Those students who are interested in using or developing software like STORM to solve PSD problems may consider writing their own program (or phone app) for one of the modules in STORM. Here are the two STORM manuals that have been published to date:

- Emmons, H., Flowers, A.D., Khot, C.M. & Mathur, K. (2001). *STORM 4.0: Quantitative Modeling for Decision Support*. Cleveland, OH: Storm Software Inc. ISBN 1-893435-156. **This is an abridged User Manual (including the student version of the software) that is available from** http://www.directtextbook.com/prices/9781893435155#des**.**
- Emmons, H., Flowers, A.D., Khot, C.M. & Mathur, K. (2001). *STORM 3.0: Quantitative Modeling for Decision Support*. Cleveland, OH: Storm Software Inc. ISBN 0-13-847450-8. **This is the original User Manual that describes in complete detail the use of the software and of each module.**

Lecture Schedule:

Date	Source of Materials	Topic/s to be covered in the Lecture
3/27	Groover, 513-516 Groover, 516-518	▪ Discussion of the Syllabus ▪ Overview of Lean Manufacturing ▪ Waste = Costs + Delays ▪ Waste Elimination = Cost Avoidance + Throughput Gains + Reduced Consumption ▪ Can you Recognize the ***Eight Types of Waste***? ▪ *In-Class Exercise:* Analysis of the Layout of a Forging Cell ▪ Importance of Insitu Observation in the Gemba ("Place of Work") ▪ Importance of Videotaping in PSD and Work Design ▪ Importance of IE-related Work Experience in PSD and Work Design **HOMEWORK: For the Class Discussion that we will have in the next lecture, PLEASE read the following Case Studies on Lean Manufacturing that are posted on Carmen:** ▪ Master Halco Implements Continuous Improvement with Kaizen ▪ Getting Lean at Senior Flexonics Ketema Division
3/27		▪ **Each team must let me know the names of their team members** ▪ **Each team must let me know in which 15-minute slot between 8:30 a.m. and 10:15 a.m. (say, 8:30 – 8:45) they wish to present for Assignments 1 and 2**
3/29		*Class Discussion:* Case Studies on Lean Manufacturing: ▪ Master Halco Implements Continuous Improvement with Kaizen ▪ Getting Lean at Senior Flexonics Ketema Division
IE Methods for Production Systems Design (PSD)		
4/3	Groover, Chapter 9 Groover, Chapter 9	**QUIZ #1** Operations Analysis (aka Process/Methods Analysis) ▪ PSD using a Process Flow Chart ▪ PSD using a Spaghetti Diagram

[7] Instead of purchasing this book at www.lean.org, you can get it at a heavily discounted price from the Barnes & Noble bookstore in the basement of Central Classrooms building.

4/5		**[Continued from Previous Lecture]** Operations Analysis (aka Process/Methods Analysis)
4/10	Groover, Section 11.1 Groover, Sec. 3.4	**QUIZ #2** Facility (and Workplace) Layout Planning and Design ▪ *Video-aided Lecture:* Single-Piece Flow (with Work Cells) ▪ Characteristics of a Lean ***and*** Flexible Cell Layout Design ▪ STORM DEMO: Computer-aided Cell Layout Design
4/12	Groover, Chapter 5 Tompkins, 176-179 Tompkins, 179, 181 Tompkins, 180-181 Tompkins, 182-184 Tompkins, 184-186	Material Handling and Storage Systems ▪ Definition of Material Handling ▪ Principles of Material Handling ▪ Material Handling Audit Checklist ▪ Material Handling System Equation ▪ Material Handling Planning Chart
4/17	Groover, Chapter 10 Groover, Chapter 12+Chapter 13	**QUIZ #3** ▪ **Guest Lecture (George Bishop, West Munroe Partners):** Time and Motion Studies for Work Design ▪ *Video-aided Lecture:* Introduction to Work Measurement and Direct Time Studies
Case Study on Production Systems Design		
4/19		▪ *Video-aided Lecture:* Toast Kaizen ▪ Analysis of the Current State ▪ Analysis of the Future State ▪ *In-Class Exercise:* Complementing Lean Tools with IE Methods ▪ Waste Elimination ▪ Operations Analysis ▪ Facility Layout ▪ Material Handling ▪ Time Studies and Work Measurement ▪ Resource-constrained Activity Scheduling
4/24		**QUIZ #4** ▪ *Video-aided Lecture:* The Goal – A Process for Ongoing Improvement (POOGI) ▪ **[Continued from Previous Lecture]** *In-Class Exercise:* Constraint-driven Process Improvement: What is the real constraint in the Toast Kaizen – the Butter or the Toaster? ▪ Root Cause Analysis ▪ 5 Why's Questioning
4/26		▪ **[Continued from Previous Lecture]** *In-Class Exercise:* Complementing the Toast Kaizen with Activity Scheduling and Job Sequencing ▪ *In-Class Exercise:* Scheduling a Linear Multi-machine Production System producing Many Products
5/1	**Team Presentations**	**Assignment #1: Case Studies on Production Systems Design**
Components of a Lean Production System		
5/3	Groover, Sec. 20.2.2	▪ *Video-aided Lecture:* Quick Changeover for Lean Manufacturing ▪ *Video-aided Lecture:* Setup Reduction for JIT ▪ *Case Study:* Setup Reduction on a Cold Forging Press at Hirschvogel Inc.
5/8	Groover, Sec. 20.4.2	**QUIZ #5** ▪ *Video-aided Lecture:* 5S's at Boeing Co. ▪ Why 5S is not ***JUST*** about Housekeeping ▪ Checklists for Assessment and Sustainment ▪ STORM DEMO: Computer-aided Layout for Tool Storage at a High-Mix Assembly Workstation
5/10	Groover, Sec. 20.4.2 Groover, Sec. 20.3.1 & 20.3.2	▪ *Video-aided Lecture:* Visual Controls ▪ *Video-aided Lecture:* Mistake Proofing (Poka-Yoke)
5/15	Groover, Sec. 20.2.1	**QUIZ #6** ▪ *Video-aided Lecture:* Kanban Systems ▪ Typical Information Content of a Kanban ▪ Types of Kanbans ▪ Mechanics of Pull Scheduling using Kanbans ▪ *Video-aided Lecture:* Kanban Systems
5/17	Groover, Sec. 20.3 Groover, Sec. 8.4 & Sec. 20.3 Groover, Sec. 8.4 & Sec. 20.3	▪ *Video-aided Lecture:* Right-sized Equipment ▪ *Video-aided Lecture:* Lean Automation ▪ *Video-aided Lecture:* Flexible Small Lot Production for JIT

Using Value Stream Mapping for Production Systems Design (PSD)		
5/22	Carmen [Source: www.Lean.org] R&S, Part I R&S, Part II R&S, Part III	**QUIZ #7** ▪ *Video-aided Lecture:* Mapping your Value Stream ▪ What is Value Stream Mapping? (In the words of Dr. James Womack aka "Dr. Lean") ▪ Getting Started with Value Stream Mapping ▪ Data Collection, Icons for VSM, Drawing a ***Current*** State Map and "Reading Into" the ***Current*** State Map to Assess an Existing Production System **NOTE:** For this exercise (Acme Stamping), the Data Set and Factory Flow Layout appear at the end of the R&S textbook, and the Current State Map is shown on Pages 28-29. ▪ "Reading Into" a ***Future*** State Map to Understand the "Guts" of ***Lean***, TPS and the "Pull System" for Production Control and Scheduling **NOTE:** For this exercise (Acme Stamping), the Data Set and Factory Flow Layout appear at the end of the R&S textbook, and the Future State Map is shown on Pages 70-71.
5/24		▪ *Video-aided Lecture:* Toast Value Stream Mapping ▪ *Class Discussion:* A3 Report for the Current State of the Toast Value Stream
5/28	**NO CLASSES**	**Memorial Day**
5/29	Carmen	**QUIZ #8** ▪ Process Analysis using Value Stream Mapping ▪ **Guest Lecture (Curt Keaton):** Using IE and Lean Tools to Balance and Improve a Complex Assembly Line at Emerson Network Power
5/31	**Team Presentations**	**Assignment #2: Improvement of a Production System using IE Methods and Lean Tools**

In-Class Quizzes (65% of Final Grade): The Lecture Schedule indicates when a quiz will be given during each week of the course. Unless otherwise announced, the quiz will be slotted for the first 30 minutes of the class. The quiz questions will be based on the two lectures in the previous week, homework assignments, lecture materials **and** relevant sections from the textbook. **There will be no make-up quizzes since I will drop the lowest quiz score when calculating the final grade.**

Assignment #1 (10% of Final Grade): This team-based *(Team Size: 6)* assignment requires that each team make a 15-minute presentation to summarize a case study that describes how a service/manufacturing enterprise implemented different IE methods and/or TOC/Lean/Six Sigma tools for PSD. *Each team will be exclusively assigned any one of the following case studies:*

- A topic that interests your team for which you have found at least one (maybe more?) case studies?
- Airline Catering
- Classroom
- Collision Repair
- Dentistry
- Document Management and Printing Services
- Education
- Family Practice
- Government
- Horticulture
- Hospitals
- Landscaping
- Laundromat
- Marketing Services (Ad Agency)
- Medical Center
- Modular Homebuilding
- Services
- Postal Services
- Public Schools
- Radiation Oncology
- Sterilization Process
- Supplier Improvement

Criteria for grading a presentation will be as follows:

- (1 slide @ 1 pts.) Description of the business and key problems that were addressed
- (1 slide @ 1 pts.) A table that lists all the problem-solving tools/methods that were used
- (3 slides @ 2 pts./slide = 6 pts.) Using graphics and text, each slide should present details of a major problem and method**s**/tool**s** that were used to solve/address it
- (1 slide @ 2 pts.) A table that presents a list of the changes/improvements that were made and, *for each change/improvement that was made*, the Before vs. After values of a key quantifiable metric used to measure the extent of the improvement achieved. *I wish to see quantitative values in the Before vs. After columns of this table!*

Since these case studies will be assigned to teams on a First-Come First-Serve basis, the earlier that each team makes its choice, the better are the chances that they will get a topic/domain that the entire group is interested in! ***Attendance at these presentations is a must for all students because they will give you much information beyond what could be taught in class due to time constraints.***

Assignment #2 (25% of Final Grade): Almost any work that we do is done within a production system comprised of customers, people, materials, tools, equipment, work instructions and procedures, business regulations, etc.! For example, in the *Toast Kaizen* video where the production system made something as simple as a slice of buttered toast, you saw how I began with a videotape of the entire process, created a variety of charts to describe that process and conducted quantitative analysis with the information contained in those charts to develop, justify and prioritize various recommendations/ideas for improving the system. Besides the factories, hospitals, distribution centers, airports and other large production systems, we are surrounded by small service businesses such as landscapers (how does one plan the mowing of somebody's lawn?), kitchen or bath remodelers (how does one install a granite kitchen countertop?), carpenters (how does one assemble a storage cabinet or window?), restaurants (how do orders flow in the kitchen?), grocers (how does one replenish shelves throughout the store?), office workers (how can delays and errors in document and decision flows between departments (or teams) be eliminated?), auto repair (how does one standardize the process for repairing cars that have suffered varying levels and locations of collision damage?), etc. Would you agree that your computer is a production system because how you organize your folders influences the time it takes you to find any **AND** all the information you seek?

In the interest of fairness, consistency and competition, I have decided that for this team-based assignment *(Team Size: 6)* all teams will select any local pizza-making small business as the "Production System" that they will analyze, improve and re-invent using the methods taught in this course! In order to give all teams a flying start, I have posted on Carmen a case study *Applying Lean in Small Business* that I obtained from a consultant. It ought to serve as an excellent benchmark for this assignment. Each team must do the following:

(i) Talk to the owner and employees at the pizza place and ask them to describe key problems associated with their current operations ex. Does it take too much time to complete an order? Is there too much manual work that is laborious and/or repetitive? Is the scrap rate too high, or is there too much rework? Are the setup and/or cycle times for certain steps too high? Are there ergonomics and safety issues? Is the process, or maybe even the facility, inflexible and unable to accommodate requests for customization? Does the layout of the workplace and/or the storage systems and/or material handling practices cause delays and quality problems? Does the equipment fail repeatedly? Is the delivery of tools, materials, gauges, etc. poorly scheduled? Are there no Standard Work Instructions to train new employees and ensure consistent quality? etc.

(ii) Develop appropriate charts that were taught in class to analyze the system ex. Time Study Analysis, Assembly Precedence Diagram, Process Flow Chart, Spaghetti Diagram, Root Cause Analysis, Material Handling Analysis Chart, 5S Checklist, Gantt Chart, etc.

(iii) Use the charts to identify different problems in the work processes and the overall system.

(iv) Develop IE and/or TOC/Lean/Six Sigma solutions to eliminate or mitigate the problems.

(v) Justify the improvements to be gained using quantitative metrics.

Criteria for grading a presentation will be as follows:

- (1 slide @ 1 pts.) This first slide will display the Course #, names of team members and a catchy title like "BuckIE's Help <Name of Pizza Business> Make Mucho Bucks". *Be creative (and funny too!) when choosing this title!* ☺
- (1 slide @ 2 pts.) A brief description (preferably including pictures) of the business, including a tabulation of all the problems that were listed by the owner and employees of the business

Each of these next (7) slides should:

(i) have the title "Identifying <Type of Waste> Waste" for one of the Seven Types of Waste

(ii) display the charting tool taught in class (or any other appropriate analysis) that "caught" it --- <u>In addition</u>, you could include a photo that shows a significant occurrence of that waste
(iii) measure the quantity (or cost) of that waste

- ❑ (1 slide @ 1 pts.) Production of defective parts *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Overproduction *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Excessive inventories *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Unnecessary processing steps *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Unnecessary movement of people *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Unnecessary travel and handling of materials *Helpful Hint:* See Section 9.3 and Section 20.1.
- ❑ (1 slide @ 1 pts.) Workers waiting *Helpful Hint:* See Section 9.3 and Section 20.1.

Each of these next (8) slides should:
(i) have as its title the particular element(s) of PSD that is(are) being improved
(ii) clearly describe your idea(s) for improvement
(iii) quantify the benefit/s to be gained by implementing the idea(s)

- ❑ (1 slide @ 1 pts.) Motion Economy **and** Work Design *Helpful Hint:* See Section 10.2.
- ❑ (1 slide @ 1 pts.) Facility Layout *Helpful Hint:* Use Spaghetti Diagram, Flow Process Chart, From-To Chart, etc.
- ❑ (1 slide @ 1 pts.) Material Handling **and** Storage Systems *Helpful Hint:* Use Material Handling Analysis Chart.
- ❑ (1 slide @ 1 pts.) 5S **and** Ergonomics *Helpful Hint:* Use the 5S Checklist. In addition, check out this paper on Lean Ergonomics which is available online*:* Walder, J. et al. (2007, November). *Integrating Lean Thinking & Ergonomics: Utilizing Material Handling Assist Device Solutions for a Productive Workplace*. Published by the Material Handling Industry of America www.MHIA.org.
- ❑ (1 slide @ 1 pts.) 5S **and** Visual Inventory Control *Helpful Hint:* See Chapter 20 and use the 5S Checklist posted on Carmen.
- ❑ (1 slide @ 1 pts.) Setup Reduction *Helpful Hint:* See Chapter 20.
- ❑ (1 slide @ 1 pts.) Error-Proofing *Helpful Hint:* See Chapter 20.
- ❑ (1 slide @ 1 pts.) Right-sized Equipment **and** Autonomation *Helpful Hint:* See Pages 225-227.

This slide is extremely important

- ❑ (1 slide @ 2 pts.) A table that summarizes all the improvement ideas that were proposed and potential benefits to be gained from implementing each of those ideas. *Each benefit should be quantified using the appropriate Units Of Measure (UOM)!*

This is the "I-Challenge-You-to-Re-Invent-the-Pizza-making-Small-Business-Completely" slide

- ❑ (1 slide @ 5 pts.) Draw a schematic layout of an automated pizza-making shop --- Select system components (dough mixer, ingredients preparation and delivery modules, conveyors, measurement sensors, packaging machines, robots for handling, scheduling software, etc.) that *<u>sensibly (not idiotically)</u>* automate the entire process from order intake to order shipment --- Ensure that the automation is influenced by the best practices of Lean (say, an oven that captures waste heat and re-routes it to a chamber that keeps warm pizzas waiting to be delivered), Six Sigma (say, an Excel macro that keeps track of customer complaints and other quality defects reported by customers) and TOC (say, an electronic scheduling board that alerts idle employees to move to that area where the system bottleneck currently resides)

Attendance at these presentations is a must for all students because they will give you much information beyond what could be taught in class due to time constraints.

Appendix 3

Syllabus for Undergraduate Course on Facilities Design

ISE541 Facilities Design
Spring 2012
Call Number: 11111
Instructor: Shahrukh A. Irani
Instructor's Contact Information: 688-4685, irani.4@osu.edu
Instructor's URL: http://ise.osu.edu/biosketch_SIrani.cfm
Course Audits: None
Course Prerequisites: ISE501, ISE520, ISE521, ISE540
Class Meeting Time: 10:30 a.m. – 12:18 a.m. Tue & Thur
Classroom: Room 220, Journalism Building
Number of Credits: 4

Course Objectives: Based on the ABET Program Outcomes, at the completion of this course it is expected that students will have:

- Received a strong foundation in the interrelationships and interdependencies between the key areas of Facilities Design **(ABET 3k)**
- Mastered the use of Operations Research models for design and evaluation of a manufacturing (or service) facility layout **(ABET 3a, 3b)**
- Mastered the use of software tools in combination with practical constraints and environmental considerations for design and evaluation of a manufacturing (or service) facility layout **(ABET 3b)**
- Learned how a good manufacturing (or service) facility layout complemented by suitable material handling, storage and communication systems relates to Lean, Six Sigma, Agile Manufacturing, Distributed Teams and Virtual Cells, etc. **(ABET 3h, 3j)**
- Engaged in a process of "learning by practicing the theory that was taught in class" by doing a team-based project on the design and evaluation of a manufacturing (or service) facility layout of a local company **(ABET 3c, 3d, 3g)**

ABET Program Outcomes that are addressed by this Course:

- **ABET Program Outcome 3(a):** An ability to apply knowledge of mathematics, science and engineering
- **ABET Program Outcome 3(b):** An ability to design and conduct experiments, as well as to analyze and interpret data
- **ABET Program Outcome 3(c):** An ability to design a system, component or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
- **ABET Program Outcome 3(d):** An ability to function on multidisciplinary teams
- **ABET Program Outcome 3(f):** An understanding of professional and ethical responsibility
- **ABET Program Outcome 3(g):** An ability to communicate effectively
- **ABET Program Outcome 3(h):** The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
- **ABET Program Outcome 3(j):** A knowledge of contemporary issues
- **ABET Program Outcome 3(k):** An ability to use the techniques, skills and modern engineering tools necessary for engineering practice

ABET Program Outcomes that <u>may not</u> be addressed by this Course: Since the course may not address the following ABET Program Outcomes, I encourage you to suggest to me how we could possibly modify the current make-up of the course to address the outcomes listed below:

- **ABET Program Outcome 3(e):** An ability to identify, formulate and solve engineering problems
- **ABET Program Outcome 3(i):** A recognition of the need for, and an ability to engage in life-long learning

Textbooks [REQUIRED]:

- Tompkins, J.A., White, J.A., Bozer, Y.A. & Tanchoco, J.M.A. (2010). *Facilities Planning*. 4th Edition. Hoboken, NJ: John Wiley. ISBN 978-0-470-44404-7.
- Emmons, H., Flowers, A.D., Khot, C.M. & Mathur, K. (2001). *STORM 4.0: Quantitative Modeling for Decision Support*. Cleveland, OH: Storm Software Inc. ISBN 1-893435-156. **This is an abridged version of the User Manual which includes the student version of the software and can be purchased at** http://www.directtextbook.com/prices/9781893435155#des**.**
- Emmons, H., Flowers, A.D., Khot, C.M. & Mathur, K. (2001). *STORM 3.0: Quantitative Modeling for Decision Support*. Cleveland, OH: Storm Software Inc. ISBN 0-13-847450-8. **This is the comprehensive version of the User Manual and can be purchased online.**

Lecture Materials: Prior to every class, please check Carmen to see if I have added any lecture materials for that day. **If I have done so**, then please bring those materials to class because I will use them during the lecture. If necessary, I will complement these notes posted online with in-class handouts.

Course Software: STORM is an Operations Research software package that contains a wide range of basic quantitative models taught in many IE courses. I use STORM for the sake of convenience and familiarity because it is very easy to learn to use this simple OR package on one's own. However, in case of any difficulty, I encourage you to meet me during office hours, preferably in groups, to learn the use of this package. In addition, I will be giving several in-class demos to complement the lectures. Alternatively, you could use BLOCPLAN, SPIRAL, VIP-PLANOPT, EXCEL SOLVER, LINDO, CPLEX, AMPL, ARENA, etc. as appropriate. For further information on this software, please contact Prof. Kamlesh Mathur, STORM SOFTWARE, 23811 Chagrin Blvd., Suite LL60, Beachwood, OH 44122. Phone: (216) 464-1209, Email: kxm6@case.edu.

Lecture Schedule:

Date	Source of Materials	Topic/s to be covered in the Lecture
3/27	Tompkins (Chapter 1)	▪ Discussion of the Syllabus ▪ Introduction to Facility Layout
3/27		▪ **Each team must let me know the names of their team members** ▪ **Each team must let me know in which 15-minute slot between 10:30 a.m. and 12:15 p.m. (say, 10:30 – 10:45) they wish to present their Term Project**
3/29	Carmen Carmen Carmen	Assessment of an Existing Facility Layout: ▪ Checklist #1: Assessment based on Lean Thinking/Toyota Production System ▪ Checklist #2: Assessment based on IE Principles ▪ How To Read a Plant – FAST ← **This article can be downloaded at http://casestudy.co.in/wp-content/uploads/2010/06/read-a-plant-HBR.pdf**
4/3	Tompkins (Chapter 3) & Carmen	**QUIZ #1** Design For Flow (DFF): Principles and Practices for Effective Design of Facilities
4/5	Carmen	**← IN-CLASS EXERCISE TO REVIEW ISE540 MATERIAL →** Basic Quantitative Evaluation of a Facility Design: ▪ Producing the Spaghetti Diagram for a Single Routing ▪ Using the Spaghetti Diagram to take a "Gemba Walk" ▪ Recording and costing all Instances of Waste observed during the "Gemba Walk" ▪ Evaluating an Entire Facility using the Spaghetti Diagram for a Single Routing

4/10	Tompkins (Chapter 3) & Carmen	**QUIZ #2**
		Advanced Quantitative Evaluation of a Facility Design:
		▪ Producing the From-To Chart for a Large Sample of Routings
		▪ Converting the From-To Chart into a Spaghetti Diagram
		▪ Evaluating an Entire Facility using the Spaghetti Diagram for a Large Sample of Routings
		  ▪ Line Of Sight Efficiency (LOSE) computed from the From-To Chart
		  ▪ Surrogate measures of material handling cost ex. Volume*Distance Score, Revenue*Travel Time, Labor and equipment depreciation for MH equipment, etc.
		  ▪ "Go See" measures (WIP, 5S Checklist, Safety/Ergonomics, etc.)

4/12	Tompkins (Chapter 2)	Data Requirements for Facility Layout
4/17	Tompkins (Chapters 3 & 6) Carmen	**QUIZ #3** ▪ Basic Types of Facility Layouts ▪ Classification of Layouts for Manufacturing and Assembly Facilities
4/19	Tompkins (Chapter 6) Carmen Carmen	Procedures for Design of Facility Layouts: ▪ Systematic Layout Planning (SLP) ▪ Production Flow Analysis (PFA) ▪ Integration of SLP and PFA

4/24	Tompkins (Chapter 6)	**QUIZ #4** Computer-aided Design of a Process Layout for an Entire Facility
4/26	Tompkins (Chapter 3)	Computer-aided Design of a Cellular Layout for an Entire Facility
5/1		**QUIZ #5** *Video-aided Lecture:* Customer Focused Manufacturing *Objectives of this Lecture:* When you view the video, make notes on the best practices being used at the following levels of the organization --- ▪ Individual machine in the cell ▪ Cell ▪ Factory within which this cell operates in combination with other cells and supporting departments ▪ External environment (markets, competitors, business strategies, vendors, etc.) in which the factory operates
5/3	Tompkins (Chapters 3 & 6)	Computer-aided Design of a Multi-product Multi-machine Manufacturing Cell ▪ Prior work that needs to be done ▪ Impact of travel distance between workstations on cell performance ▪ Basic material flow patterns in a cell: Why should every cell have a U shape? ▪ Characteristics of a good cell layout ▪ Clusters of cell shapes based on the Roman alphabet ▪ Using PFAST and STORM to customize the shape of a cell based on its flow complexity
5/8	Carmen	**QUIZ #6** Computer-aided Design of a Workstation where Many Parts (or Tools) must be Stored for Multi-Product Assembly
5/10	Carmen	Computer-aided Design of a Point-Of-Use Facility Layout for a Vertically-integrated Make-To-Order Fabrication and Assembly Facility ▪ Motivation for developing Value Network Mapping (VNM) ▪ Data collection and transformation into a PFAST input file ▪ Data analysis using PFAST ▪ Facility layout using the PFAST outputs ▪ Assembly scheduling using MS Project ▪ Limitations of the VNM method ▪ Future enhancements in the VNM method
5/15	Tompkins (Chapter 5)	Material Handling ▪ Definition of Material Handling ▪ Principles of Material Handling ▪ Material Handling Audit Checklist ▪ Material Handling System Equation ▪ Material Handling Planning Chart ▪ *Video-aided Lecture:* Flexible Material Handling
5/17		**Team Presentations:** Commercial Material Handling Equipment and Systems *Objectives of this Lecture:* Each team must research a specific material handling equipment (or system) described in Appendix 5B in the textbook. Find an online source of good information about it and briefly explain to the class the uses, advantages/limitations, costs, etc. of that equipment (or system).
5/22	**Source:** www.lean.org [Paper available on Carmen]	**QUIZ #7** ▪ Four Steps to a Lean Material Handling System ▪ Water Striders
5/24		How Facilities Design Influences Production Control, Shop Scheduling and Resource Utilization ▪ **Example #1:** Multi-product Multi-machine Manufacturing Cell ▪ **Example #2:** Multi-product Multi-department Fabrication Facility
5/28	**NO CLASSES**	**Memorial Day**
5/29	**NO LECTURES**	**Term Project Presentations**
5/31	**NO LECTURES**	**Term Project Presentations**

Homework Assignments: Every week's lectures will require that the work done in the class be completed at home. Students will need to use this homework for the quiz which will be given the next week.

In-Class Quizzes (70% of Final Grade): The Lecture Schedule indicates when a quiz will be given during each week of the course. Unless otherwise announced, the quiz will be slotted for the first 30 minutes of the class. The quiz questions will be based on the two lectures in the previous week, the homework that would have to be done to complement the classroom work **and** relevant sections from the textbook. **There will be no make-up quizzes since I will drop the lowest quiz score when calculating the final grade.**

Term Project with Final Presentation (30% of Grade): The term project requires each team of students (Team Size: 2) to evaluate the facility layout of a local company and recommend improvements relating to the facility layout, material handling, storage containers, ergonomics, production scheduling, etc. Thereby, the project will make students spend time in industry learning how to connect theory and practice. *Every team is welcome to submit Interim Reports to me for evaluation, if that will help them to improve their Final Presentation at the end of the quarter.* However, any Interim Report and the Final Presentation must be prepared using Powerpoint. That's right! You do not have to write a looooooooooooooong report in Word. That way you will learn to make a report concise without loss of detail and content. Also, the use of Powerpoint slides will encourage the maximum use of text callouts, photographs, graphics, graphs, tables and flowcharts to present observations, analyses, results and recommendations.

An Interim Report must summarize the activities performed for the Term Project until the day of submission. *If any team decides to submit an Interim Report to me, it is recommended that copies of data sheets used, analyses done, a list of materials read, conclusions made, etc. be attached.* This will allow me to provide feedback and directions for further study. Be sure that your report provides sufficient information to show that you accomplished work – reading, industry visits, data analysis, computer-aided analysis, etc. Past experience has shown that steady progress on the project with my input and guidance based on the Interim Reports has always resulted in a satisfactory final performance.

Criteria for Grading your Term Project Presentation: At the end of the quarter, each team must make a 15-minute presentation on their Term Project. Criteria for grading a presentation will be as follows:

- (1 pts.) Title Page
- (1 pts.) Table Of Contents
- (1 pts.) Description of the Business
- (1 pts.) Description of the Facility
- (1 pts.) Description of the Products
- (2 pts.) Analysis of Marketing Information about the Products produced in the Facility
- (2 pts.) Improvement of the Existing Layout of the Facility
- (2 pts.) Improvement of the Existing Material Handling Systems, Procedures, etc. in the Facility
- (2 pts.) Improvement of the Existing Storage Systems, Procedures, etc. in the Facility
- (2 pts.) Improvement of the Existing Workplace Organization (Housekeeping) in the Facility
- (2 pts.) Improvement of the Existing Ergonomics and Safety in the Facility
- (2 pts.) Improvement of the Existing Shopfloor Communication Systems, Procedures, etc. used for Order Tracking, Inventory Control, etc.
- (2 pts.) Improvement of the Condition and Maintenance of Existing Equipment and Tools in the Facility
- (2 pts.) Improvement of the ERP System's Use for Connecting the Front Office to the Shopfloor
- (5 pts.) Potential Impact/Benefits of your Ideas
- (1 pts.) Aesthetics (visual appeal, correct choice of background colors (readability), creative use of figures and text, etc.)
- (1 pts.) Professionalism demonstrated by the team (business casual dress code, poise during presentation, well-planned hand-off's between members of the team, clear evidence of balanced sharing of workload/effort, etc.)

Some Parting Advice concerning your Term Project Presentation: Do not forget what your ultimate goal is! You can assess an existing facility till the cows come home and you can have the most grandiose and elegant of ideas imaginable. But, if you cannot show how your ideas/recommendations will significantly impact key performance metrics, then all your efforts would have been in vain. So, the bottom line is that every recommendation you offer should involve some measurable economic (or related) benefits such as (i) increased $ales, (ii) reduced operating costs, (iii) reduced on-hand inventories (raw materials, WIP, purchased parts and finished goods), (iii) reduced energy costs, recycling costs, transportation costs, etc., (iv) reduced floorspace requirements (maybe a planned expansion is avoided because of your layout proposal?), and so on. So, when you decide to suggest an improvement on any slide, ask yourselves questions such as:

- Would this change/improvement reduce Operator Motion Waste ex. could the overtime paid to employees be reduced because they will spend less time walking, moving material, etc.?
- Would this change/improvement reduce Overprocessing Waste because now machines that are non-constraints will not be run "just to keep them busy" ex. could energy costs and the overtime paid to employees be reduced?

- Would this change/improvement reduce energy costs ex. powered conveyors are eliminated and replaced by gravity-feed roller conveyors?
- Would this change/improvement reduce Material Handling Waste ex. could the labor, operation and maintenance costs of material handling equipment usage be reduced?
- Would this change/improvement reduce Inventory Waste ex. could lower WIP be held in queues at only the constraint machines?
- Would this change/improvement reduce floorspace allocated for non-value-added activities, such as material handling, inventory (raw materials, WIP and finished goods), scrap/rework, etc.?
- Would this change/improvement allow for the unused floorspace be leased to another business? Or could rental costs be reduced (if the facility is being leased)?
- Would this change/improvement reduce the time, errors, etc. for communications and information sharing between machine operators, material handlers, support services (maintenance, purchasing, HR, etc.), production control, etc.?
- Would this change/improvement promise a potential increase in $ales because fewer incomplete orders will constitute WIP at any given time, more orders will be completed and shipped per day, expediting costs will be lower due to fewer overnight deliveries, etc.? Or could the reduced lead times to complete orders help to take business away from competitors due to reduction in idle capacity, less scrap/rework, in-sourcing of work that is currently done by vendors, etc.?
- … and so on…..

Potential Sponsors for your Term Project: Some teams may already have a member (or members) working at local companies that would be happy to sponsor their Term Project. However, if some teams lack these contacts and make a strong case that they will deliver value from their Term Project, then here are some contacts at companies that have partnered with us in the past:

- **Horton Ambulance:** Alwyn Aliwarga, aliwarga.1@osu.edu, (512) 554-8468
- **Emerson Network Power:** Curt Keaton, curt.keaton@emerson.com, (614) 841-6905
- **Hirschvogel Inc.**: Klaus Juergen-Schmitt, Klaus-juergen.schmitt@hirschvogel.com, (614) 707-9971
- **Safecor Health:** Sarah Cooney, SCooney@safecor.com, (800) 447-1006 x3104
- **Ometek, Inc.:** Paul Siders, PSiders@ometek.com, (614) 861-6729 x28
- **PSB (A Division of White Castle):** David Rife, RifeD@whitecastle.com, (614) 559-2482
- **Sutphen Towers, Inc.**: Yoseph Setiadi, Yoseph.Setiadi@sutphen.com, (614) 554-3176

Content of the Term Project Presentation

- (1 slide) **Title Page:** Give your project a title that, in a single sentence, summarizes the scope of your work ex. Re-Layout of a Fabrication Facility.
- (1 slide) **Table Of Contents:** The Title and Page # for every slide should be shown (maybe with hyperlinks inserted since you are using Powerpoint?)
- (1 slide) **Description of the Business:** Overview of Product Mix, Growth Patterns for Product Mix, Types of Markets served, Pictures (or CAD drawings) for a key product (or products), etc. *See Table 2.4 in the textbook.*
- (1 slide) **Description of the Facility:** Sketch of the Layout, List of Departments, Dimensions (overall, for each department, etc.), Building Architecture, Expansions/Additions to the Facility, and other information.
- (1slide) **Description of the Products:** Photos, BOM, assembly precedence diagram, CAD drawing, exploded view, sample routings for components or subassemblies, etc. *See Chapter 2 in the text.*
- (1 slide) **Analysis of the Product Mix produced in the Facility:** Use Pareto Analysis (aka P-Q Analysis) to assess whether the facility layout is appropriate for the type/s of business segments/markets that the company is trying to serve, diversity of products, etc. *See Section 2.4.1 in the textbook on how to analyze sales data using Pareto Analysis.*

****** THESE NEXT SLIDES ARE VERY IMPORTANT ******

Each of these next slides that you create should display one or more of the following that you used to scope your idea and compute the Before vs. After benefits from implementing the idea: (1) **Chart** (Spaghetti Diagram, Flow Process Chart, Value Stream Map, Operations Process Chart (OPC), Multi-Product Process Chart, From-To Chart, Material Handling Analysis Chart, etc.) **OR** (2) **Software Use** (done using STORM, PFAST, ARENA, etc.) **OR** (3) **Data Analysis** (done using EXCEL, MINITAB, ARENA, etc.) **OR** (4) **Checklist** (done using any of the three checklists that I have referenced in my lectures)

- (1 slide) **Improvement of the Existing Layout of the Facility:** Are there any pairs of machines (or departments) that are not hand-off distance apart from each other (or adjacent to each other), respectively? Could you re-locate any machine to a different location? Could you bring several machines together and co-locate them in a cell? Could you buy an extra machine and locate it appropriately in the facility? How much of the floorspace is used for Value-added work compared to Necessary-but-Not-Value-added work and Non-Value-added work? *Examples: The area that corresponds to the footprint of an operational machine is VA; the area that corresponds to material handling aisles is NNVA and the area that corresponds to a rack where scrap, obsolete inventory or old machine parts are stored is NVA.*
- (1 slide) **Improvement of the Existing Material Handling Systems, Procedures, etc. in the Facility:** What prevents one-piece flow of products between all pairs of machines with significant traffic between them? Why is not the flow of material continuous throughout the facility, as in a distribution center with continuously operating conveyors? Could not all material handling be manual involving small carts and no forklifts, cranes, etc.? Is material handling between any pair of workcenters based on PUSH or PULL scheduling? *See Chapter 5 in the textbook, especially* the *Principles of Material Handling* and the *Material Handling Audit Checklist.*
- (1 slide) **Improvement of the Existing Storage Systems, Procedures, etc. in the Facility:** Pick the most-used storage container in use on the shopfloor for moving materials between pairs of machines with significant material flow between them. How many hours of work does a full container represent? What material handling equipment is necessary to move it? Is there a direct correlation between the distance of travel and the quantity of WIP that is contained in a container i.e. does the container size increase as the distance of travel increases? What prevents use of smaller storage containers of a standardized design? Are there too many different types of containers in use i.e. could some rationalization and standardization be done? Could the existing storage racks be replaced by vertical storage systems, such as the Modula vertical storage system (www.SystemStorageSolutions.com)? Is it easy to know what parts are contained in a typical container, how many pieces, delivery dates, etc.? *See Chapter 7 in the text or visit websites like www.mmh.com for info on storage containers.*
- (1 slide) **Improvement of the Existing Workplace Organization (Housekeeping) in the Facility:** For this slide, focus on a single location in the facility. Do you see Standard Work Instructions hung on the equipment? Are quality control/inspection records, procedures, gauges, etc. up-to-date and prominently displayed and, of

course, used? Is Error-Proofing actively practised? *See ISE540 course notes on 5S that were posted on Carmen **and** Section 3.6.4 in the textbook.*

- (1 slide) **Improvement of the Existing Ergonomics and Safety in the Facility:** For this slide, focus on a single location in the facility where the loading/unloading or material handling work being done is known to be potentially risky. *See ISE560 course notes else Google "Lean Ergonomics" for online resources. In particular, this paper which is available online would give you enough ideas for this slide:* Walder, J. et al. (2007, November). Integrating Lean Thinking & Ergonomics: Utilizing Material Handling Assist Device Solutions for a Productive Workplace. Published by the Material Handling Industry of America www.MHIA.org.
- (1 slide) **Improvement of the Existing Shopfloor Communication Systems, Procedures, etc. used for Order Tracking, Inventory Control, etc.:** How do machine operators, material handlers, supervisors, production controllers, and other personnel directly involved with manufacturing and material flow communicate with each other? How visible to all operators are visual displays of operations-related information relating to Time, Costs and Quality of the work they do i.e. on the average, how much time does it take for any operator or supervisor to obtain information pertaining to an order? How instantaneous are the flows of information (machine breakdowns, schedule changes, pick up/drop off requests for material handling, quality defects, manufacturing-related clarifications/instructions, etc.) in the facility? How do operators communicate with each other to synchronize and prioritize their work plans? How complete are the work instructions, etc. received by the operators? How are the operators told about key production control statistics? Are the right key performance measures that drive the speeds at which they work, products they produce, etc. posted on displays in the facility? Would the products sold by commercial vendors such as www.magnatag.com, www.adaptivedisplays.com, www.ledgible.com, www.signalguys.com and www.kentdisplays.com be useful? Are the displays in the facility manual (or electronic); how many are there; are they placed at the correct locations in the facility? *See Section 3.6.4 in the textbook.*
- (1 slide) **Improvement of the Condition and Maintenance of Existing Equipment and Tools in the Facility:** What is the condition of the equipment in general across the facility? Is the shopfloor clean with aisles clearly painted, different areas color-coded to indicate the type of work done there, etc.? Do equipment operators get immediate response to equipment problems from the Maintenance department? Are the equipment operators capable of, or even authorized for, doing some basic maintenance on their equipment. *See Category 8 (Pages 8-9) in the paper **Read a Plant – FAST** by Eugene R. Goodson.*
- (1 slide) **Improvement of the ERP System's Use for Connecting the Front Office to the Shopfloor:** How much is production impacted by delays and other inefficiencies caused by poor workflows (decisions, data, documents, etc.) between the Front Office and the shopfloor? Is the ERP system being used to its full potential? Could the use of Smart Phones, Smart Boards (www.leankitkanban.com), etc. help to address some of the problems?

****** THIS NEXT SLIDE IS EXTREMELY IMPORTANT ******

Each of these next slides that you create should display one or more of the following – **Charts** (Spaghetti Diagram, Flow Process Chart, Value Stream Map, Operations Process Chart (OPC), Multi-Product Process Chart, From-To Chart, Material Handling Analysis Chart, etc.), **Layout Design** (done using STORM, PFAST, ARENA, etc.), **Data Analysis** (done using EXCEL, MINITAB, ARENA, etc.) – that you used to scope your idea and compute the Before vs. After benefits from implementing the idea.

(1 slide, 5 pts.) **Potential Impact/Benefits of your Ideas:** This slide should display a single table that lists all the tangible/quantifiable benefits to be gained from each of the ideas for improvement that have been proposed earlier in the presentation. For example, say you wish to show that the new layout will facilitate visual management and communications. To do this, you could show that the Line Of Sight Efficiency (LOSE) of the new layout will be higher than that of the existing layout.

Appendix 4

Syllabus for Undergraduate Course on Production Control and Scheduling

ISE542 Design and Implementation of Production Control Systems
Spring 2011
Call Number: 11696
Instructor: Shahrukh A. Irani
Instructor's Contact Information: 688-4685, irani.4@osu.edu
Instructor's URL: http://ise.osu.edu/biosketch_SIrani.cfm
Course Audits: No Audits Allowed
# of Credits: 4
Grading: Graded on the A-E Scale
Course Prerequisites: ISE501, ISE504, ISE520, ISE521, ISE540
Class Meeting Time: 8:30 a.m. – 10:18 a.m. Mon & Wed
Classroom: Room 205, Boyd Laboratory

Course Objectives:

- To obtain an overview of some of the core topics in Production Control and Scheduling (PCS) and place them in the context of Value Stream Maps, which provide an effective "bringing together" of the subject matter and IE skills taught in ISE540, ISE541 and ISE542
- To study the use of Operations Research in PCS, especially to enhance and extend the use of Value Stream Mapping
- To gain experience in computer implementation of PCS models, especially to enhance and extend the use of Value Stream Mapping
- To relate industry "buzzwords" (Theory Of Constraints, Just-In-Time (JIT), Toyota Production System, Lean, etc.) to Operations Research, the science that powers the ISE profession

ABET Program Outcomes To Be Addressed By This Course:

- **ABET Program Outcome 3(a):** An ability to apply knowledge of mathematics, science and engineering
- **ABET Program Outcome 3(b):** An ability to design and conduct experiments, as well as to analyze and interpret data
- **ABET Program Outcome 3(c):** An ability to design a system, component or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability
- **ABET Program Outcome 3(d):** An ability to function on multidisciplinary teams
- **ABET Program Outcome 3(g):** An ability to communicate effectively
- **ABET Program Outcome 3(h):** The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context
- **ABET Program Outcome 3(j):** A knowledge of contemporary issues
- **ABET Program Outcome 3(k):** An ability to use the techniques, skills and modern engineering tools necessary for engineering practice

Since the course may not address the following ABET Program Outcomes, I encourage you to suggest to me how we could possibly modify the current make-up of the course to address the outcomes listed below:

- **ABET Program Outcome 3(d):** An ability to function on multidisciplinary teams
- **ABET Program Outcome 3(e):** An ability to identify, formulate and solve engineering problems
- **ABET Program Outcome 3(f):** An understanding of professional and ethical responsibility
- **ABET Program Outcome 3(i):** A recognition of the need for, and an ability to engage in life-long learning

What is Production Control? It is the set of decision-making mechanisms that:

- Determines *what products* will be produced by a factory, *how much of each product* will need to be produced and *when each product* must be produced in each of a sequence of production periods
- Coordinates the factory's production schedule with the supply schedules of various vendors who are delivering raw materials, parts and sub-assemblies to the factory

- Coordinates the information flows and activities of the different departments in the factory, both manufacturing and manufacturing support, that contribute to the manufacture (and assembly) of parts (and products)

Textbooks [REQUIRED]:

- Rother, M. & Shook, J. (1999). *Learning To See: Value Stream Mapping To Create Value And Eliminate Muda*. Brookline, MA: The Lean Enterprise Institute. ISBN 0-9667843-0-8. To purchase this book, go to www.lean.org and use the discount code "ISE542" to get a 20% student discount that I negotiated with LEI. If you have questions concerning this purchase, please direct them to Rachel Regan, who is the Director of Events and Community Support at the Lean Enterprise Institute. Her phone # is 617-871-2900 and email address is info@lean.org. **ALTERNATIVELY**, the Barnes & Noble bookstore in the basement of Central Classrooms building sells this book for business students!

Textbooks [OPTIONAL]:

- Sipper, D. & Bulfin, R.L. (1997). *Production: Planning, Control and Integration*. New York, NY: McGraw-Hill.
- Harris, R., Harris, C. & Wilson, E. (2003). *Making Materials Flow: A Lean Material Handling Guide for Operations, Production Control and Engineering Professionals*. Brookline, MA: The Lean Enterprise Institute. ISBN 0-9741824-9-4.
- Smalley, A. (2004). *Creating Level Pull: A Lean Production System Improvement Guide for Production Control, Operations and Engineering Professionals*. Brookline, MA: The Lean Enterprise Institute. ISBN 0-9743225-0-4.

Lecture Materials: Prior to every class, please check Carmen in advance if I have added any course content for that day's lecture. If I have done so, then please bring that material to class because I will use it during the lecture. I will make it a point to upload the lecture presentation to Carmen immediately after the lecture is delivered on any given day. If necessary, I will complement these notes posted online with in-class handouts.

Course Software: The book – Emmons, H., Flowers, A.D., Khot, C.M. and Mathur, K. (2001). *STORM 4.0: Quantitative Modeling for Decision Support.* Euclid, OH: Lakeshore Communications – is a manual-cum-textbook for this package. Copies are available in BE351E, the ISE Computer and Control Laboratory or can be purchased from SBX. I use STORM for the sake of convenience and familiarity because it is very easy to learn to use this simple Operations Research package on one's own. However, in case of any difficulty, I encourage you to meet me during office hours, preferably in groups, to learn the use of this package. In addition, I will be giving several in-class demos to complement the lectures and homework assignments. Alternatively, one could use EXCEL SOLVER to solve the problems that will be discussed in class or assigned for homework. Use of any advanced mathematical programming software such as LINDO or CPLEX is also acceptable. *Note that STORM will also be the modeling software used in ISE532! For further information on this software, please contact: STORM Software Inc., P.O. Box 22658, Cleveland, OH 44122* (**Websites for purchasing the student version and manual:** http://www.directtextbook.com/editions/hamilton-emmons-storm-4-0 **or** http://www.crowncustompublishing.com/cgi-bin/commerce.cgi?cart_id=1130078929.19593&product=Books&pid=32).

Lecture Schedule:

Date	Readings in the Text	Topic/s to be covered in the Lecture
3/28	Carmen Carmen	❑ Discussion of Syllabus ❑ Essential Components of a Production Control and Scheduling (PCS) System
3/28		❑ **Students must form teams for the Term Project (Team Size: 4-5)** ❑ **Each team must email me the names of the members in their team** ❑ **Each team must sign up for a time slot for the Term Project presentation on June 1**
3/30	Carmen	❑ **[Continued from previous class]** Essential Components of a Production Control and Scheduling (PCS) System **NOTE: For the exercise (Acme Stamping) that will be used for this lecture, the Data Set and Factory Flow Layout appear inside the back cover of the R&S textbook. The Current State Map is shown on Pages 32-33 and the Future State Map on Pages 78-79.**

	R&S, Part I, 1-12 R&S, Inside Back Cover R&S, Appendix A R&S, Part II, 13-38	❑ Representing a Production System using Value Stream Mapping • Getting Started with Value Stream Mapping • Data Collection • Icons for VSM ❑ Drawing a ***Current*** State Map and "Reading Into" the ***Current*** State Map to Assess an Existing Production System
4/4	R&S, Part II, 13-38	**QUIZ #1** **NOTE: For the exercise (Acme Stamping) that will be used for this lecture, the Data Set and Factory Flow Layout appear inside the back cover of the R&S textbook. The Current State Map is shown on Pages 32-33 and the Future State Map on Pages 78-79.** ❑ How a VSM Visually Captures the Interactions and Inter-dependencies between the Essential Components of a Production Control and Scheduling (PCS) System ❑ *Video Screening:* Value Stream Mapping at Jotul America
4/6	Carmen & S&B, 570-574	Problems In A Typical Production System ❑ *Video Screening:* "The Goal" ❑ *Q&A Session:* "The Goal"
4/11	R&S, Part III, 39-54 **=== If Time Permits ===** **=== If Time Permits ===**	**QUIZ #2** **[Continued from previous class]** *Q&A Session:* "The Goal" ❑ *Case Study:* Applying TOC in the Real World ❑ "Reading Into" a ***Future*** State Map to Understand the Inner Workings of TPS and the "Pull System" for Production Control and Scheduling ❑ *Video Screening:* "Theory Of Constraints" ❑ *Q&A Session:* "Theory Of Constraints"
4/13	Carmen Carmen Carmen	❑ Typical Reasons for Loss of Capacity on any Bottleneck Resource ❑ Using an Ishikawa Diagram (aka Cause and Effect Diagram) to "Exploit The Constraint" and Gain Back Lost Capacity ❑ Analysis of Constraint Capacity Utilization using OEE and TPM
Where are we at this point in our "Learning Journey"? TOC does not provide complete details on any of the approaches suggested to design an effective and efficient production control and scheduling system. For example, what are the parameters and execution rules for the Pull Scheduling strategy called Drum-Buffer-Rope?		
4/18	Carmen & S&B, 382-390	**QUIZ #3** Single (Bottleneck) Machine Scheduling *WITHOUT* a Capacity Constraint
4/20		**[Continued from previous class]** Single (Bottleneck) Machine Scheduling *WITHOUT* a Capacity Constraint
4/25	Carmen	**QUIZ #4** Single (Bottleneck) Machine Loading *WITH* Capacity Constraints (using STORM) ❑ Contrasting Takt Time (Time/Unit) versus Throughput ($/Hour) as Metrics for Performance and Capability Analysis of a Value Stream ❑ Basic Model: Knapsack Problem ❑ Advanced Models: Variations of the Knapsack Problem involving Setup Times, Batch Sizes, Multiple Products, Groups of Jobs, etc. ❑ How to incorporate the "Typical Reasons for Loss of Capacity on any Bottleneck Resource" into these models?
4/27		**[Continued from previous class]** Single (Bottleneck) Machine Loading *WITH* Capacity Constraints (using STORM)
5/2	Carmen & S&B, 404-412 Carmen & S&B, 404-412	**QUIZ #5** Single (Bottleneck) Machine Loading and Job Sequencing with Sequence-dependent Setup Times ❑ Case I (*WITHOUT* a Capacity Constraint): ❑ Case II (*WITH* a Capacity Constraint):
Where are we at this point in our "Learning Journey"? It is rare that a real-world production system consists of a single machine! However, the saying that "a chain is only as strong as its weakest link" is the basis for TOC and its DBR methodology for Pull Scheduling. Similarly, Value Stream Mapping, which is based on how Toyota's engineers design their production facilities, also assumes that, by scheduling the Pacemaker, the entire Value Stream can be scheduled.		
5/4	Carmen	❑ Introduction to Operations Scheduling and Shopfloor Control Systems ❑ Introduction to Jobshop Scheduling
5/9	Carmen & S&B, 445-452 **Guest Speaker**	**QUIZ #6** ❑ Jobshop Scheduling using Dispatching Rules (based on Single Machine Scheduling) ❑ **Software Demonstration:** LEKIN (Academic Scheduling Software)
5/11	Carmen & S&B, 426-431	Flowshop Scheduling ❑ Loading and Scheduling of a Multi-Machine Flowshop (Case I: *WITHOUT* a Capacity Constraint, # of Machines = 2): Johnson's Algorithm
5/16		**QUIZ #7**

	Carmen & S&B, 426-431	Flowshop Scheduling ❑ Loading and Scheduling of a Multi-Machine Flowshop (Case I: *WITHOUT* a Capacity Constraint, # of Machines ≥ 3): Campbell-Dudek-Smith Heuristic
5/18	Carmen	Loading and Scheduling of a Multi-Machine Flowshop (Case II: *WITH* a Capacity Constraint, # of Machines = 2): ❑ Impact of Capacity Constraints on Flowshop Schedules ❑ MIP Model for Identification of the Bottleneck in the Flowshop ❑ Integration of Classical Scheduling Algorithms, OPT Rules, TOC and Lean (One-Piece Flow, Cellular Layout, Parallelization of Work, etc.) to Schedule a Capacity-constrained Flowshop ❑ Lean Tools that help to ensure continuous (zero inter-machine transfer delays) flow between machines in a 2-machine flowshop cell in order that the schedules produced by theoretical Flowshop Scheduling algorithms can work (Single-Piece Flow Cells, Setup Reduction for Zero Changeover Times, Poka-Yoke, TPM, Autonomation, etc.)?
5/23	Carmen & S&B, 574-577	**QUIZ #8** Production Planning and Scheduling for an Assembly Jobshop ❑ Utility of the "Steps in TOC" ❑ Utility of OPT Rules and Priority Dispatching Rules for Scheduling an Assembly Jobshop ❑ Estimation of Lead Times for Material Requirements Planning
5/25		**[Continued from previous class]** Production Planning and Scheduling for an Assembly Jobshop
5/30	**NO CLASSES**	**Memorial Day**
6/1	**8:30 a.m. – 10:15 a.m.**	**TERM PROJECT PRESENTATIONS**

Special Topics

- ❑ (S&B, 438-445) Jobshop Scheduling using DBR
- ❑ (S&B, Ch. 7, Sec. 2) Using TOC for Master Production Scheduling
- ❑ S&B, 326-329) Machine Loading over Multiple Periods WITH Capacity Constraints
- ❑ Software Demos (Our "experiments with MS Project, TACTIC (ask Murgiano), PREACTOR (ask Liddell or Quinn or Ouillet)

In-Class Quizzes: Every Monday (See "Lecture Schedule"), unless otherwise announced, a quiz will be given in the first 30 minutes of the class. The quiz questions will be based on the two lectures in the *previous* week, homework assignment **and** readings in the textbook relevant to those two lectures. **There will be no make-up quizzes since I will drop the lowest quiz score when calculating the final grade.**

Term Project: The term project is a team project (Team Size: 4, at most 5) to develop a simulation model for the Acme Stamping case study discussed in Part IV of the Rother & Shook book *Learning To See*. Starting with a base case that is the solution that the authors develop, simulate changes in that base case to demonstrate what would happen to the original results if "perturbations (or disturbances)" that violate the many assumptions the authors make that the Value Stream represents a static/deterministic manufacturing system. Recall that the "Key Questions for Future-State Design" that are put forth by the authors of *Learning To See* are:

(i) What is the Takt Time?
(ii) Will you build to a finished goods supermarket, or directly to shipping?
(iii) Where can you use continuous flow processing?
(iv) Where will you need to use supermarket pull systems to control production of upstream processes?
(v) At what single point in the production chain (the "pacemaker process") will you schedule production?
(vi) How will you level the production mix at the pacemaker process?
(vii) What increment of work will you consistently release and take away at the pacemaker process i.e. Level the Production Volume by producing Every Part Every Interval (EPEI) at the pacemaker?
(viii) What process improvements will be necessary for the Value Stream to flow as your Future-State design specifies?

Now, if you study the methods used in the Rother & Shook book, the authors use really simplistic quantitative methods, and make drastic assumptions and simplifications in order to make their assembly line extremely easy to re-design! For example, their Future State could easily be "perturbed" if the operating conditions change, such as demand changes that cause the takt time to vary with time **OR** more than one product is scheduled for production (which would cause for loss of capacity at the pacemaker due to setup changes) **OR** the pacemaker experiences random breakdowns or scheduled stoppages for preventive maintenance thereby losing capacity (which compromises the Takt Time) **OR** parts shortages occur that force the pacemaker to remain idle **OR** due dates are imposed on certain orders, and so on.

Interim Progress Report/s for Term Project: *These reports are not going to be graded but are welcome at any time if any team seeks input on whether they are on the right track in their project.* Each project team must submit an interim progress report that summarizes the activities performed for the term project till the date of submission of the report. *It is recommended that copies of data sheets used, analyses done, conclusions made, etc. be attached.* This enables me to provide feedback and directions for further study. Be sure that your report provides sufficient information to me that you accomplished work – reading, industry visits, data analysis, computer work – towards the project because this report will be graded! Past experience has shown that steady progress on the project with my input and guidance based on the interim progress report has always resulted in a satisfactory final presentation. *Please ensure that some tangible effort to make progress is described in the interim progress report because that is the basis on which I provide input, suggestions and guidance to proceed further.*

Final Presentation for Term Project: At the end of the quarter, each team must make a 15-minute presentation that presents only the results, recommendations and benefits of their project. Criteria for grading a presentation will be as follows:

- (25 pts. = 5 pts. per perturbation X *Any* 5 *different* perturbations) Your simulation model must demonstrate the Before vs. After impact on the performance of the Future State when you made each (or some combination) of 5 different perturbations to the operational parameters of the initial (static) Future State presented in the book *Learning To See*
- (3 pts.) Aesthetics of your Powerpoint presentation (visual appeal, correct choice of background colors, readability of text, creative use of text to explain content of figures or tables, etc.)
- (2 pts.) Public speaking and presentation skills demonstrated by the group (poise, confidence, eye contact with the audience, etc.)

Attendance at these presentations is a must for all students because they will give you much information beyond what could be taught in class due to time constraints.

Alternatives for the Term Project: Instead of the Value Stream simulation project, a team may consider doing any one of the alternative projects that I have described below:

- **In ISE540, you assessed and suggested improvements in the Current State for the main Value Stream at Emerson Network Power. Take *any 5* of your suggestions, preferably those that relate to the subject matter taught in this course i.e. Production Control and Scheduling, and fully develop the specifics required to implement those suggestions.**
- Evaluate a commercial Finite Capacity Scheduler (PREACTOR). If you go to http://www.preactor.com/Home.aspx you can download a free copy of Preactor Express. Alternatively, the demo version of Version 9 (easier install!) is available for free and can be downloaded at http://www.quasc.com/evaluationold.htm whereas the demo version of Version 11 (harder install, ignore the HASP document as it does not apply to demo copies) can be downloaded at http://www.quasc.com/evaluation.htm . I am also trying to get Version 11 installed on our computer networks for both laboratories on the 3rd floor.
- Evaluate a commercial Flowshop Simulator that has made available for free to students by its vendor, www.optisol.biz. Please email its developer, Dr. Prasad Velaga, at Prasad_Velaga2003@yahoo.com to receive a demo version of his software.

Appendix 5

Syllabus for Graduate Course on JobshopLean

INDE7397 Flexible and Lean Production Systems

Autumn 2014

Instructor: Dr. Shahrukh Irani, President, Lean & Flexible, llc, 4102 Pensacola Oaks Lane, Sugar Land, TX77479, **E:** ShahrukhIrani1023@yahoo.com, **P:** 832-475-4447, **Website:** www.LeanandFlexible.com.

Acknowledgments: This course was made possible with the support and encouragement of Dr. Gino Lim, Chair, Department of Industrial Engineering, University of Houston.

Background for this Course: Lean was originally developed for ***low***-mix ***high***-volume (LMHV) manufacturing systems. I developed JobshopLean for ***high***-mix ***low***-volume (HMLV) manufacturing systems while I was on the faculty of the Department of Integrated Systems Engineering at The Ohio State University. *JobshopLean integrates Lean, IE and OR ("Lean IE") to support the implementation of Lean in any non-assembly discrete manufacturing (or production) system.* The Department Of Defense (DOD) funded me from 2001-2012 to adapt and enhance Lean for custom forge shops that supply forgings used in advanced weapon systems. Custom forge shops are job shops which makes them among the hardest high-mix low-volume (HMLV) facilities in which to implement Lean. By 2006, I was convinced that, if I wanted industry to take JobshopLean seriously, I myself needed first-hand work experience in implementing it. So, after 22 years in academia, I decided to gain that much-needed work experience and took a full-time job in industry starting on September 1, 2012. Having gained some much-needed industry experience, I desired to return to teaching and got a part-time teaching position at the University of Houston in 2014. I would like to teach future IE's how to succeed (or fail) at implementing JobshopLean.

Companies where JobshopLean Projects were Done in the Past:

Type of Jobshop	Representative Companies
Electronics Assembly	• EFTC Corporation
Electronics Repair	• PDSI Corporation
Forging	• Bula Forge • Consolidated Industries • Hirschvogel Inc. • TECT • Trinity Forge
Fabrication	• C.O.W. Industries • HP Products • Ometek Inc.
Foundry	• PRL Industries
Machining	• G&G Mfg. Co. • Hardy Machine and Design Inc. • Hoerbiger Corporation of America • PR Machine Works • Tecomet

Student-centric Objectives of this Course:

- To teach a systematic methodology for design of a Flexible and Lean (FLean) facility layout for any high-mix low-volume (HMLV) manufacturing facility
- To teach a systematic methodology for implementing Lean in high-mix low-volume (HMLV) manufacturing facilities

- To teach quantitative methods and software tools for implementing JobshopLean
- To teach the support systems and Lean tools that are essential for efficient and effective operation of manufacturing cells
- To apply the methods and tools taught in the course in a team-based project in industry

Industry-serving Goal of this Course: The course is intended to prepare students to do internships in those companies that sponsor the Term Projects for the course, or other HMLV manufacturers interested in implementing JobshopLean in their facilities.

Grading: The major motivation for a student to take this course is to learn a body of knowledge that will make him/her a strong candidate for an internship with a company that wishes to implement Lean and/or JobshopLean**.** The grading distribution is as follows:

- *Homework (50%):* To develop a student's knowledge and competence in some of the Lean tools that are needed to implement Lean/JobshopLean.
- *Term Project (50%):*
  - To develop a student's knowledge and competence in designing a facility layout that will facilitate the implementation of JobshopLean.
  - To develop a student's knowledge and competence in using IE science and/or Lean Six Sigma tools to solve an actual problem posed by an industry sponsor.

Electronic Textbook: The DVD is available for purchase from The UPS Store #4854, 5680 Hwy 6 South, Missouri City, TX 77459, located in the Riverstone shopping center (in front of Palais Royal & Kohl's).

- *Mode of Payment:* Please make a check payable to "The UPS Store 4854" in the amount of $54.13 else payments can also be made in cash.
- *Store Hours:* M-F 8 a.m. – 7 p.m.; Sat 10 a.m. – 4 p.m.
- *Contact Person:* Ms. Reema Patel
- *Phone:* (281) 403-3280, *Email:* store4854@theupsstore.com, *Website:* http://store4854.upsstoreprint.com.

Suggested Readings on Cellular Manufacturing:

- Black, J.T. & Hunter, S. L. (2003). *Lean Manufacturing Systems and Cell Design.* Dearborn, MI: Society of Manufacturing Engineers. ISBN 98765-432-1.
- Burbidge, J.L. (1996). *Production Flow Analysis for Planning Group Technology.* New York, NY: Oxford University Press Inc. ISBN 0-19-856459-7.
- Hales, L.H. & Andersen, B. (2002). *Planning Manufacturing Cells*. Dearborn, MI: Society of Manufacturing Engineers. ISBN 0-87263-549-X.
- Hyer, N. & Wemmerlov, U. (2002). *Reorganizing the Factory: Competing through Cellular Manufacturing*. Portland, OR: Productivity Press. ISBN 1-56327-228-8.
- Irani, S. A. [Editor]. (1999). *Handbook of Cellular Manufacturing Systems.* New York, NY: John Wiley. ISBN 0-471-12139-8.
- Nyman, L. R. (1992). *Making Manufacturing Cells Work.* Dearborn, MI: Society of Manufacturing Engineers. ISBN 087263-419-1.

Suggested Readings on Lean Manufacturing:

- Allen, J., Robinson, C. & Stewart, D. (2001). *Lean Manufacturing: A Plant Floor Guide*. Dearborn, MI: Society of Manufacturing Engineers.
- Lane, G. (2007). *Made-To-Order Lean: Excelling in a High-Mix Low-Volume Environment.* New York, NY: Productivity Press. ISBN 978-1-56327-362-9.
- Nicholas, J. (2011). *Lean Production for Competitive Advantage*. New York, NY: CRC Press.
- Phillips, D.T. & Black, J.T. (2013). *Lean Engineering*. VirtualBookworm.com Publishing.
- Wilson, L. (201). *How to Implement Lean Manufacturing*. New York, NY: McGraw-Hill.

Course Software: I strongly urge every student to buy the student version of this software which comes with a user manual – Emmons, H., Dale F.A., Khot, C.M. & Mathur, K. (2001). *STORM 4.0: Quantitative Modeling for Decision Support.* Euclid, OH: Lakeshore Communications

(http://www.directtextbook.com/prices.php?q=1893435156&qtitle=&qauthor=&qkeywords=&qisbn=1-893435-156&redirected=yes). ISBN 1-893435-156.

Homework Assignment:

- **Task #1:** All teams must work on this assignment – *Design of a Future Factory Layout to Combine Both Buildings using the Flow Assessment App and PFAST Software*. It is intended to teach "a systematic methodology for design of a Flexible and Lean (FLean) facility layout for any high-mix low-volume (HMLV) manufacturing facility".

  Homework Must Be Submitted in Class Every Week: At the start of each week's lecture, every team should submit a report that demonstrates how they applied what was taught in the previous week's lecture for this assigment.

- **Task #2:** In preparation for the lectures in Week #9 (October 24) and Week #10 (October 31), each team must pick one of the case studies that I have posted on Blackboard. In addition, I ask that each team search websites, such as www.mmsonline.com and www.thefabricator-digital.com, for articles on **Lean Machine Shops** and/or **Lean Tools** and/or **Manufacturing Cells in Job Shops**. Then they must prepare a Powerpoint presentation (1 slide per tool) on Lean tools, such as 5S, shadow boards, electronic scheduling boards, water striders, automated tool cribs, etc., that were successfully implemented in the cells

Term Project – Option #1:[8]

This option is recommended for a team that has at least one member who has a car so the team can visit Hardy Machine and Design Inc. at least once a week to work on their project! The Term Projects are being sponsored by – Hardy Machine and Design, Inc., 5737 Windfern Road, Houston, TX77041. Their President is Ankur Goel (Ankur.Goel@HardyMachine.com, 713-690-3335 x115). Each project is being championed by an employee at Hardy Machine and Design who has a stake in the successful implementation of his idea. A team can choose to do any one of the following projects at this machine shop:

- (*Champion at Hardy Machine: Jim*) Implementation of a Tool Crib
- (*Champion at Hardy Machine: Jaspal*) Elimination of Inter-Building Transfers of Steady Rests used on Lathes
- (*Champion at Hardy Machine: George and/or Pooke*) Visual Supermarket to Store and Locate Active Orders using a "Valet Parking Token System"
- ~~5S Audit Display Board for Employee Performance Assessment and Progress Charting the Implementation of an Employee's Suggestion(s)~~
- ~~Detailed Design of a Pilot Manufacturing Cell~~
- ~~Real-Time Monitoring of CNC Machines using Predator (www.Predator-Software.com)~~
- ~~Production Planning and Control (incl. Order Tracking) with SysPro~~

Weekly Visits to Hardy Machine Design Inc.: I am available to work with the student teams doing their Term Projects at Hardy Machine and Design Inc. for half-day on any day of the week. My first preference is Friday (AM) because the lecture would follow in the afternoon on the same day. If that is not possible due to some students having to attend the Graduate Seminars on Friday mornings, then I would ask that all teams coordinate with each other and let me know which of the other days in the week (AM or PM) that all of them can synchronize to come to the company. Thank you!

First Visit to Hardy Machine Design Inc.: I desire the teams working at Hardy Machine and Design Inc. start visiting the company from the SECOND WEEK of the semester.

Term Project – Option #2:

This option is recommended for a team that has no member with a car! In Lecture #2 on September 5, you will see the Toast Kaizen video. You will realize that even though many IE charts were created to analyze the assembly process for making a buttered slice of toast, there is no Standard Work Instruction (SWI) for the ToPS (Toast Production System)! Each team will study the video and develop a SWI for the process of making toast.

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[8] If we cannot get a local company to sponsor the Term Project, then the project will focus on the industrial applications of the PFAST (Production Flow Analysis and Simplification Toolkit) software to implement a variety of Continuous Improvement projects in any high-mix low-volume manufacturing facility.

Motivation for this Term Project: NTEA (www.ntea.com), The Association for the Work Truck Industry, is seeking an educational session on *Development of Standard Work Instructions for Building a Work Truck* at their annual conference in 2015. If some of the students taking this course could learn this Lean tool, then after the conference in Spring 2015 semester, there is a good chance that one or more NTEA members in Houston (or even Texas) may want to hire them as interns!

References on SWI: I am willing to loan the following books that can be passed around between the teams doing this project:

- The Productivity Press Development Team. 2002. *Standard Work for the Shop Floor*. Productivity Press, New York, NY.
- Niederstadt, J. 2010. *Standardized Work for Non-Cyclical Processes*. CRC Press, New York, NY.
- Martin, T.D. & Bell, J.T. 2011. *New Horizons in Standardized Work*. CRC Press, New York, NY.
- Kato, I. & Smalley, A. 2011. *Toyota Kaizen Methods: Six Steps to Continuous Improvement*. CRC Press, New York, NY.

Purchasing a copy of the *Toast Kaizen* DVD: The DVD is available at http://www.shopgbmp.org/toastkaizendvd.html . I would suggest that TWO teams spread the cost of buying the DVD equally across all members with one member agreeing to pay more so he/she can keep the DVD for future use after the course is over.

Term Project – Guidelines, Rules and Expectations:

Team Size: 4-5 members.

Interim Progress Reports: These weekly reports that must be submitted in class every week are intended to help me provide feedback and directions for further investigations by the team. This report must consist of 3 sections: (i) a summary of the group's activities, (ii) activities performed by *each* member of the team and (iii) key results obtained. It is recommended that copies of data sheets used, analyses done, conclusions made, etc. be attached to each progress report.

Final Presentation: Each project team must make a presentation at the end of the semester. The duration of each presentation will be 30 minutes (max). The presentation must describe the activities performed, key results and recommendations generated by their project and valid justification of benefits to be gained from each recommendation. The final presentation must have the following sections:

- Title Page
- List of Recommendations for Implementation
- Summary of Key Analyses done for each Recommendation
- Justification of Benefits from each Recommendation
- Summary of Benefits from All Recommendations
- Suggestions for Future Work
- Comments about the Project Experience

Deliverables: On the day of their presentation, each team must (i) give me a CD containing their final presentation and (ii) email their presentation to the sponsor company.

Lecture Topics: Please see the Appendix for the detailed content of every lecture.

Week	Date	Lecture Topic
1	Aug 29	Introduction to the Course
2	Sep 5	An Introduction to Continuous Improvement and Lean Principles
3	Sep 12	Essential Foundation for JobshopLean
4	Sep 19	A Quick-Start Approach for Implementing JobshopLean
5	Sep 26	(LAT A) Waste Assessment in the Current Facility Layout
6	Oct 3	(LAT B) Product Mix Segmentation
7	Oct 10	(LAT C) Feasibility of Cell Formation

8	Oct 17	(LAT D) Design of a Multi-Product Multi-Machine Cell
9	Oct 24	Essential Lean Tools for Every Cell
10	Oct 31	Cells In Action
11	Nov 7	Fundamentals of Cell Scheduling
12	Nov 14	Design of a Cellular Manufacturing System
13	Nov 21	The Stamping Out Chaos Simulation© of a Cell
14	Nov 28	**NO CLASSES (THANKSGIVING)**
15	Dec 5	In-Class Presentations of Term Projects

APPENDIX

Electronic Textbook: The DVD is available for purchase from The UPS Store #4854, 5680 Hwy 6 South, Missouri City, TX 77459, located in the Riverstone shopping center (in front of Palais Royal & Kohl's).

- *Mode of Payment:* Please make a check payable to "The UPS Store 4854" in the amount of $54.13 else payments can also be made in cash.
- *Store Hours:* M-F 8 a.m. – 7 p.m.; Sat 10 a.m. – 4 p.m.
- *Contact Person:* Ms. Reema Patel
- *Phone:* (281) 403-3280, *Email:* store4854@theupsstore.com, *Website:* http://store4854.upsstoreprint.com.

Lecture Topics:

- Unless otherwise stated, all readings for each lecture are chapters from the book: Irani, S.A. Hybrid Cellular Layouts: New Ideas for Design of Flexible and Lean Layouts for Jobshops**.**
- "LAT #" refers to sections **in the workbook: Irani, S.A.** Lean Advisory Tools for Jobshops.
- "DISC #" refers to one of the discs in the 5-disc e-learning package: Irani, S. A. *Foundations of JobshopLean for High-Mix Low-Volume Manufacturers*.
- "e-Handout" means that the material is available in the e-textbook developed for the course.

Week #	Readings	Lecture Topic/s
1	**Introduction to the Course**	
	e-Handout	Discussion of the Course Syllabus: • Textbooks • Grading • Term Project • Summer Internships • Etc.
	Video/Lecture	Introduction to Lean Manufacturing
	Videos on Lean Implementation	◊ Lean Manufacturing in a Small Shop ◊ Lean Manufacturing at TAC ◊ Lean Manufacturing at Miller SQA
	e-Handout	◊ CASE STUDY: Master Halco ◊ CASE STUDY: Ketema
2	**An Introduction to Continuous Improvement and Lean Principles**	
	Video	Toast Kaizen (http://www.shopgbmp.org/toastkaizendvd.html)
	e-Handout	Root Cause Analysis and Improvement of the "Toast Production System" (ToPS) with IE Tools: ◊ Flow Process Chart ◊ Flow Diagram ◊ Fishbone Diagram ◊ Tree Diagram ◊ Constraint-driven Thinking ◊ Activity Sequencing and Constraint-driven Process Scheduling ◊ Etc.
	Presentations	Recognizing the Seven Types of Waste: ◊ Example: Waste Walk through the Entire Facility ◊ Example: Waste Walk through a Manufacturing Cell
	Video (DISC #3)	**How a Jobshop Developed their In-House Training Video on Waste Elimination**
3	**Essential Foundation for JobshopLean**	
	Foreword + Introduction	Why the Toyota Production System is Unsuitable for Jobshops

	DISC #1	Reduction and Simplification of Material Flows in a Factory using Production Flow Analysis (PFA)
	Ch. 1	Overview of Production Flow Analysis (PFA)
	Ch. 2	Overview of PFAST Algorithms
	Ch. 4	Computer-aided Execution of the Four Steps in PFA using PFAST
	Ch. 4	◊ Anatomy of a PFAST Analysis Report ◊ Connectivity between Various Outputs in a PFAST Analysis Report
	Ch. 2	Industrial Applications of PFAST
	e-Handout	Term Project with W.S. Darley and Co.: ◊ PFAST Input File ◊ PFAST Output File (aka PFAST Analysis Report) ◊ "Play Sheet": How to Translate the PFAST Analysis Report into Project Ideas for Implementing JobshopLean
4	**A Quick-Start Approach for Implementing JobshopLean**	
	DISC #1	**Internship Project:** SIFCO Forge Group
	Video (DISC #2)	**Internship Project:** Bula Forge and Machine Inc.
	e-Handout	Using the Waste Walk to kick-off the Quick-Start Approach: ◊ What data to collect? ◊ Flow Diagram (aka Spaghetti Diagram) ◊ Facility Walkthrough (aka Gemba Walk) ◊ Examples of the Seven Types of Waste ◊ Violations of the Principles of Design For Flow ◊ Value Added Ratio ◊ Etc.
5	**Waste Assessment in the Current Facility Layout**	
	Ch. 4 + LAT #A	From-To Charts and Flow Diagrams
	Ch. 4 + LAT #A	Line-Of-Sight Efficiency (LOSE)
	Ch. 4 + LAT #H	Volume*Distance Score
	Ch. 4 + LAT #H	Revenue*Distance Score
	e-Handout	• Quick Overview of Value Stream Mapping • Identifying Waste using a Value Stream Map
	Video	Case Study on Value Stream Mapping: Jotul America
6	**Product Mix Segmentation**	
	e-Handout	• Why Traditional Facility Layouts Have Failed High-Mix Low-Volume Manufacturers ….. Since the Days of Henry Ford! • Flexibility and Focus: Non-traditional Facility Layouts for Modern Factories
	Ch. 4 + LAT #B	P-Q Analysis
	Ch. 4 + LAT #B	PQ$ Analysis
	Ch. 4 + LAT #B	PR Analysis (Type I and Type II)
	Ch. 4 + LAT #B	PQR$ Analysis
	e-Handout	PQR$T Analysis: How to determine if a facility should have one, or more, layouts designed for different segments of the product mix?
7	**Feasibility of Cell Formation**	
	e-Handout	Interacting Sub-Problems in Cell Formation
	LAT #C	STRATEGY MAP #1: Strategies to reduce, better yet eliminate inter-cell flows of parts that utilize available capacity on shared machines distributed in several cells that ARE NOT Monuments
	LAT #C	STRATEGY MAP #2: Strategies to reduce, better yet eliminate inter-cell flows of parts that utilize available capacity on shared machines

		that ARE Monuments
	Ch. 4 + LAT #F	Rationalization of the Product Mix
	Ch. 3 & 5 + LAT #E e-Handout	• Design of a Modular Layout • **Case Study:** How Layout Modules Guided the Replacement of Several Machines by a Single Machining Center
	Ch. 3 & 5 + LAT #E	Design of a Cascading Flowline Layout
	Ch. 4 + LAT #F	Rationalization of the Product Mix
	Ch. 4 + LAT #G	Re-Engineering of "Misfit" Routings
8	**Design of a Multi-Product Multi-Machine Cell**	
	LAT #D	Design of the Layout for a Multi-Product Multi-Machine Cell • Overview of the Problem: What comes before it? • Design For Flow: Principles for Flow Planning in any Facility • Impact of Travel Distance between Workstations in a Cell • Basic Flow Patterns in a Cell: Must every cell necessarily have a U-shape? • Characteristics of a Good Cell Layout • Quick Tutorial on STORM • Cell Shapes based on Clusters of Alphabets • Role of PFAST: P-R Analysis Type IV vs. From-To Charts • Final Solution
	e-Handout	Case Study: Design of a FLean (Flexible and Lean) Manual Packings Cell
9	**Essential Lean Tools for *Every* Cell**	
	Videos	◊ Work Measurement ◊ 5S ◊ Flexible Material Handling ◊ Error Proofing (Poka Yoke) ◊ Setup Reduction ◊ Right-sized Equipment ◊ Kanban Systems ◊ Flexible Small Lot Production ◊ Visual Controls ◊ Kaizen ◊ Total Productive Maintenance ◊ Lean Automation (incl. Ultimate Factories Collection) ◊ Lean Accounting ◊ Building a Lean Culture ◊ Human Side of Lean
10	**Cells In Action**	
	Video	Each project team must view the video *Customer Focused Manufacturing* and make notes on the best practices shown being used at the following levels: • Individual Machine that operates within the Cell • Cell within which that Machine operates • Factory within which that Cell operates • (External) Environment within which the Factory operates
	Video	Each project team must view the video *Single Piece Flow* and make notes on the Lean Tools being used in the cell.
11	**Fundamentals of Cell Scheduling**	
	e-Handout	Practical Cell Scheduling using Lean, TOC, Mixed Integer Programming and Scheduling Theory
	Guest Lecture	**Software Demo:** LEKIN (or) Schedlyzer (or) FPSuite (or) FORCAM

12	**(TUTORIAL) Design of a Cellular Manufacturing System**	
	e-Handout	This case study that originally appeared in my Handbook of Cellular Manufacturing Systems (Chapter 20) presents an opportunity to review and bring together everything that has been taught in the course: • Product-Process Matrix Analysis for Part Family Formation • Capacity Requirements Analysis for Machine Allocation to Design Manufacturing Cells • Machine Duplication and Exception Operations • Cell Layout • Shop Layout • Hybrid Cellular Layouts • Scheduling of Intra-cell and Inter-cell Operations • Etc.
13	**The *Stamping Out* Chaos© Simulation of a Cell**	
	Ch. 7 + DISC #4	The simulation is based on a simple dataset for a hypothetical manufacturing cell.
14	**In-Class Presentations of Term Projects**	

Special Topics: I would be happy to deliver this lecture outside of the regular lecture schedule if even a subset of students in the class expresses interest in it.

Week #	Readings	Topic/s to be covered in the Lecture
n/a	**Value *Network* Mapping: How to Map the Complete BOM for a Complex Product**	
	DISC #1	• Motivation for developing the Value Network Mapping (VNM) method • Data collection and transformation into a PFAST Input File • Data analysis using PFAST • Facility Layout using the PFAST Analysis Report • Finite Capacity Scheduling using MS Project • Limitations/Enhancements • **Case Study:** C.O.W. Industries Inc. is a fabrication jobshop where Value Network Mapping was used to map a complete fabricated cabinet. We will review the work done and results obtained from this project.