BOSTON UNIVERSITY
COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

ME/SE 765 Production System Design

Fall 2012, T-Th 2:00-4:00pm, 15 Saint Mary's Street, Rm 105

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Course Content

ME/SE 765 addresses a general methodology for the analysis and design of Production, Manufacturing or Processing systems that operate in a *time- based-competition-marketplace* or a *time-delay-critical- environment* rendering their performance dependent on the *inventory* (or backlog) and associated *time delay* (or lead-time, system time or cycle time) required to *transform inputs* to *final products* or services.

Lead times of real production systems are almost always a sizable multiple of the sum of necessary processing times needed to perform the requisite transformation operations. From a value stream optimization point of view, this is considerable waste that proper design should strive to eliminate. The root cause of this waste is the presence of *broadly construed variability*.

For key examples of *sources of variability* consider: uncertainty (in processing, failure, repair times; demand and raw material arrival times), labor/resource/shift scheduling constraints, diversity in the processing times of multiple part types/information packets/computation jobs assigned to the same workstation/transmitter/ compiler, imbalances in the loading of serial workstations, improper design of processing lot sizes across the manufacturing floor, and the list can go on.

Objectives of Production-System-Design in the context Variability-Caused-Delays include *improving flow*, *minimizing system component variability* to the extent it is possible and cost effective, and finally *managing variability* so as to *decrease system delays* and *inventory*.

Design variables include resource capacity, (processing, storage, material handling, repair capability) layout, and production management *policies* (release, lot sizing, routing, scheduling and scarce resource allocation strategies). Although policies can be predetermined, they are actually implemented in real time such as the release of raw material to the manufacturing floor based on a predetermined Kanban level pull policy.

Network architecture and topology design issues are *not considered explicitly* in this course, but Analysis tools to evaluate alternative designs are developed.

Analysis refers primarily to the application of methodologies that provide estimates of *average system performance* measures where average is construed relative to a relevant time scale.

Performance measure examples include production throughput rates, product mix, lead times, machine utilization, and in-process-inventory. On-time performance or service rate such as the percent of time that an order is backlogged or rejected are also considered.

Sensitivity analysis focuses on the sensitivity of performance measures to design variables and policy parameters of interest (e.g., Kanban size, capacity and reliability at the various process steps).

Finally, the relevance of uncertain production system performance evaluation to Takt-time-based Just-In-Time/One-Part-Flow production management methodologies, as well as the value of using accurate performance measure estimates as input to traditional MRP/MRP-II as well as modern supply chain coordination systems are elaborated.

Following an introduction of manufacturing system approaches and lean manufacturing concepts, the course proceeds with the exposition of technical and quantitative techniques at the graduate engineering level.

The analysis and design tools developed in MN765 draw from the following areas in systems theory and operations research:

-Stochastic processes with emphasis on Markov chains and queueing theory including recent extensions to queueing networks.
-Event driven simulation concepts for efficient analysis of complex production systems that are analytically non-tractable.
-Discrete event dynamic systems theory and perturbation analysis which are recent developments allowing the extraction of second order (sensitivity or gradient) information from a single sample path (i.e. real or simulated trajectory) of a production system, and use of this information to design the associated parameters through stochastic optimization.
-Mathematical programming applications to the design of production systems through the utilization of performance and sensitivity information obtained for a finite number of trial designs, are surveyed briefly but do not receive significant attention

Whereas the underlying methodology and technical background of analysis and design tools receive considerable attention, simple application software will be made available to students for use in exercises and practical applications of the theory in required project work.

Prerequisites

A background in calculus, probability theory, matrix algebra and computer programming is required. Knowledge of operations research fundamentals (linear programming, gradient search algorithms), production system characteristics, and engineering economics is helpful but not required of the motivated student who is willing to pick it up through self study facilitated by brief in-class review.

Organization

The methodology and theory described above will be covered in formal lectures. Attendance is very important since students will have to rely extensively on notes taken during class. This is a synthetic course that does not cover material included in a single text. The instructor's notes will be distributed and will constitute the required reading for the course. A recommended text is:

Manufacturing Systems Engineering by Stanley B. Gershwin, PTR Prentice Hall,
ISBN 0-13-560608-X. This textbook is out of print but a paperback version is available from the author at reduced/reasonable cost.

Reference papers will be handed out in class. A good deal of the material on simulation can be found in A Guide to Simulation 2nd edition by P Bratley, B. L. Fox and L. E. Schrage. Other useful reference texts are Stochastic Models of Manufacturing Systems,by J. A. Buzacott and J. G. Shantikumar, or Fundamentals of Queueing Theory by D. Gross and C. Harris, Reversibility and Stochastic Networks by F. P. Kelly and Stochastic Models in Operations Research by D. P. Heyman and M. J. Sobel.

There will be graded *homework assignments* issued periodically, as well as a late *midterm* examination, which, together with class participation will account for 60% of the course grade. The remaining 40% of the course grade will be determined by each student's performance in individually completed *project papers*.

Project topics may be selected from the attached list or proposed by the student and in either case agreed upon with the instructor. Projects addressing a real problem encountered in the work environment of part time students are particularly encouraged, provided that they utilize one or more of the tools/design approaches that developed and discussed in class. Written reports are required. It is expected that projects will have a computational/software development focus, although exceptions of purely theoretical papers are possible. The objective of project work will be a synthetic implementation of tools described in class that address a real or realistic production system design, and/or evaluation problem.

Projects topics will be proposed by students and discussed individually with the instructor. Students at remote sites will meet with the instructor either during a visit by the instructor at the remote site or a specially scheduled ICV session. Of course, remote site students are welcome to visit the BU campus in Boston and arrange to meet with the instructor.

Attention: Fall 2011 Special Dates!!!

- **Thursday November 15, 2012 Midterm Examination.**
- **Monday December 17, Projects due.**

Time Schedule of Material Coverage

# of Classes	Coverage
3	Introduction and Overview. Stochastic dynamic production systems in the context of supply chain coordination. Time based competition and Little's Law.(Viewgraphs on SupplChain, LittleIntro, UncertImpact, Chapter 1, Notes)
3	Discrete and continuous time Markov Chains. (Chapter 2 and Appendices to Chapter 2, Notes)

5	Simulation theory and the finite buffer capacity transfer line. Event driven simulation. Discrete event dynamic systems and perturbation analysis (Chapter 3, Notes)
3	Analytic solution of the two-failure-prone-machine one buffer transfer line. Decomposition of a large transfer line using the two-machine fundamental block (Chapter 4, Notes).
4	Queueing networks. Jackson networks, product form solution, open queueing networks, closed queueing networks and mean value analysis. Extensions to non exponential processing time distributions (Chapter 5 of Notes).
2	Approximate modeling of queues and production planning (ProdPlanning Viewgraphs)
1	MIDTERM
2	Hierarchical decomposition for the planning and scheduling of production systems. Interaction of decision support tools including Production Planning and Lead Time Performance Evaluation.
2	No formal lectures, individual discussions on project work.

<u>Suggested Project Topics(* indicates hot topics!)</u>

I. Investigate protocols for scarce resource allocation (storage space and repair crews) in a simple stochastic production system.

Project will involve forming the Markov transition diagram for each protocol, deriving the differential equations, solving for steady state probabilities and evaluating performance measures. A 3-4 machine one buffer system is the simplest production system that can be used here.

II*. Production system simulation.

Various options here are:

@Program the event driven simulation algorithm for a transfer line and investigate the uniformization versus other simulation techniques.

@Program the event driven simulation algorithm for a transfer line and apply it to design the transfer line parameters using perturbation analysis.

@Extend and code the event driven simulation algorithm for simple tree structure production systems (as opposed to transfer line)

@Simulate and evaluate the performance of queueing network type systems (re-entrant flow lines or assembly/disassembly re-entrant systems) for different Input Control policies (random, deterministic, closed loop) and specific operation Sequencing Policies (shortest remaining processing time first, last buffer first etc.)

@Design and build a Kanban based material flow simulator.

III. Transfer line decomposition.

Some options here are:

@Code Gershwin Berman algorithm for the two machine system and implement a simple production line decomposition model based on it.

@Code "two point boundary value" type transfer line decomposition developed by Gershwin.

@Use Gershwin's "two point boundary value" type transfer line decomposition algorithm software provided to you by the instructor to:

1. design a production system's buffer capacity and machine sequencing that meets a desired production rate at minimum WIP
2. study the variability of its production, measure its ability to meet due dates, and propose ways to achieve 95% due date satisfaction performance.

IV*. Closed queueing network evaluation.

- Code "Mean Value Analysis" (MVA) algorithm and apply it to design an FMS specified up to some design parameters.
- Code the MVA algorithm with all its extensions to handle variance different from mean and multiple machines at each node. Use the algorithm to investigate the optimal inventory position needed to meet due dates at a given tardiness tolerance.
- Use a queueing network analyzer model to investigate the behavior of a real production system: Predict lead times and compare to those observed and or used in the MRP schedule.

V. Calibrate machines with exponential processing, failure, and repair times to represent a production processes with general non-exponentially distributed processing times. Use the transfer line software to investigate the behavior of the associated production system.

VI. Use Queueing Network Analyzer Software (to be made available if possible) to evaluate alternative strategies for meeting production requirements.

VII*. Cell Coordination through dynamic lead time calculations. Construct a model of a small factory consisting of at least three cells and coordinate production and WIP over a few time periods (at least four) to minimize inventory and backlog costs while meeting average production capacity for the WIP level available during each period.

IIX*. Lead time estimation for different cell layout designs. Implement in Excel a simple model that estimates queueing time at a particular workstation on the basis of the mean and variance of part type specific processing times and a fixed exponentially distributed arrival rate of raw parts obtained from the part routing sheets and the layout design of the cell. Construct approximations to deal with more than one machine per workstation and transfer lots. Model either random assignment of parts to individual machines or cooperation of all machines in the processing of a single part type until the whole transfer lot of that part type has been processed. Use this as a building block to estimate lead times of the whole cell and to evaluate different layout designs and setup strategies.

IX. Lot size impact on lead times and production planning. Use the extensions on non-exponential processing time distributions for closed and open queueing networks to capture lot size and lead time tradeoffs. If really ambitious, form and solve simple production planning optimization model.

X. Approximate modeling of joins and blocking in general networks. This is an interesting topic that I would be interested in working with one or more students on.

XI. Production Planning modeling using LP software.

XII. Student proposed topics approved by instructor. Approximate Open Queueing Network models can be used as described in power point handouts.
XIII. Case study that will be distributed by instructor. Specific set of Questions/Aspects of the case study problem can be undertaken for investigation by individual students.