Stochastic Modeling of Manufacturing Systems

Advances in Design, Performance Evaluation, and Control Issues

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Editors

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With 121 Figures
and 91 Tables

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Editorial – Stochastic Modeling of Manufacturing Systems: Advances in Design, Performance Evaluation, and Control Issues

Manufacturing systems rarely perform exactly as expected and predicted. Unexpected events always happen: customers may change their orders, equipment may break down, workers may be absent, raw parts may not arrive on time, processed parts may be defective, etc. Such randomness affects the performance of the system and complicates decision-making. Responding to unexpected disturbances occupies a significant amount of time of manufacturing managers. There are two possible plans of action for addressing randomness: reduce it or respond to it in a way that limits its corrupting effect on system performance. This volume is devoted to the second. It includes fifteen novel chapters on stochastic models for the design, coordination, and control of manufacturing systems. The advantage of modeling is that it can lead to the deepest understanding of the system and give the most practical results, provided that the models apply well to the real systems that they are intended to represent. The chapters in this volume mostly focus on the development and analysis of performance evaluation models using decomposition-based methods, Markovian and queuing analysis, simulation, and inventory control approaches. They are organized into four distinct sections to reflect their shared viewpoints.

Section I includes a single chapter (Chapter 1) on factory design. In this chapter, Smith raises several concerns that must be addressed before even choosing a modeling approach and developing and testing a model. Specifically, he discusses a number of dilemmas in factory design problems and the paradoxes that they lead to. These paradoxes give rise to new paradigms that can bring on new approaches and insights for solving them.

Section II includes Chapters 2–7 on unreliable production lines with in-process buffers.

More specifically, in Chapter 2, Enginarlar, Li, and Meerkov analyze a tandem production line and determine the minimum buffer levels that are necessary to obtain a desired line-efficiency. The work considers tandem lines with non-exponential stations and extends prior work on tandem lines with exponential servers. A fairly detailed simulation study is conducted to analyze the performance of the tandem lines. The results are used to derive an empirical law that provides an upper bound on the desired buffer levels.

In Chapter 3, Helber uses decomposition to analyze flow lines with Cox-2 distributed processing times and limited buffer capacity. First, he derives an exact solution for a two-station line. Based on this solution, he then derives an approximate, decomposition-based solution for larger flow lines. Finally, he compares the

results obtained by his decomposition method against those obtained by Buzacott, Liu, and Shanthikumar.

In Chapter 4, Colledani, Matta, and Tolio present a decomposition method to evaluate the performance of a production line with multiple failure modes and multiple products. They solve analytically the two-part-type, two-machine line and derive the decomposition equations for longer lines. They use an algorithm similar to the DDX algorithm to solve these equations to determine the production rate and other performance measures approximately.

In the next chapter (Chapter 5), Matta, Runchina, and Tolio address the question of how to increase the production rate of production lines by using a shared buffer within the system in order to avoid blocking. Simulation is used to demonstrate the gain in the mean production rate when a common buffer is used. In addition, an application of the shared buffer approach to a real case is reported.

In Chapter 6, Kim and Gershwin ask what happens if machines in a production line can either fail catastrophically (stop producing), or fail to produce good parts while continuing to produce. First, they develop a Markov process model for machines with both quality and operational failures. Then, they develop models for two-machine systems, for which they calculate total production rate, effective production rate, and yield. Using these models, they conduct numerical studies on the effect of the buffer sizes on the effective production rate.

Finally, in Chapter 7, Lee and Lee consider a flow line with finite buffers that repetitively produces multiple items in a cyclic order. They develop an exact method for evaluating the performance of a two-station line with exponentially or phase-type distributed processing times by making use of the matrix geometric structure of the associated Markov chain. They then present a decomposition-based approximation method for evaluating larger lines. They report on the accuracy of their proposed method and they discuss the effects of job variation and job sequence on performance.

Section III includes Chapters 8–13 on queueing network models of manufacturing systems.

More specifically, in Chapter 8, Van Vuuren, Adan, and Resing-Sassen consider multi-server tandem queues with finite buffers and generally distributed service times. They develop an effective approximation technique based on a spectral expansion method. Numerous experiments are utilized to demonstrate the effectiveness of their performance methodology when compared with simulation of the same systems. Their approximation methodology should be very useful for production line design.

In Chapter 9, Koukoumialos and Liberopoulos present an analytical approximation method for the performance evaluation of multi-stage, serial systems operating under nested or echelon kanban control. Full decomposition is utilized along with an associated set of algorithms to effectively analyze the performance of these systems. Finally, these approximation algorithms are utilized to accurately optimize the design parameters of the system.

In the next chapter (Chapter 10), Spanjers, van Ommeren, and Zijm consider closed-loop, two-echelon repairable item systems with repair facilities at a number of local service centers and at a central location. They use an approximation method

based on a general multi-class marginal distribution analysis algorithm to evaluate the performance of the system. The performance evaluation results are then used to find the stock levels that maximize the availability given a fixed configuration of machines and servers and a certain budget for storing items.

In Chapter 11, Van Nyen, Bertrand, van Ooijen, and Vandaele present a heuristic that minimizes the relevant costs and satisfies the customer service levels in multi-product, multi-machine production-inventory systems characterized by job-shop routings and stochastic arrival, set-up, and processing times. The numerical results derived from the heuristic are compared against simulation.

In Chapter 12, Van Houtum, Adan, Wessels, and Zijm study a production system consisting of several parallel machines, where each machine has its own queue and can produce a particular set of job types. When a job arrives to the system, it joins the shortest queue among all queues capable of serving that job. Under the assumption of Poisson arrivals and identical exponential processing times they derive upper and lower bounds for the mean waiting time and investigate how the mean waiting time is effected by the number of common job types that can be produced by different machines.

Finally, in Chapter 13, Geraghty and Heavey review two approaches that have been followed in the literature for overcoming the disadvantages of kanban control in non-repetitive manufacturing environments. The first approach has been concerned with developing new, or combining existing, pull control strategies and the second approach has focused on combining JIT and MRP. A comparison between a Production Control Strategy (PCS) from each approach is presented. Also, a comparison of the performance of several pull production control strategies in an environment with low variability and a light-to-medium demand load is carried out.

The last section (Section IV) includes Chapters 14 and 15 on production planning and assembly.

In Chapter 14, Axsäter considers a multi-stage assembly network, where a number of end items must be delivered at certain due dates. The operation times at all stages are independent stochastic variables. The objective is to choose starting times for different operations in order to minimize the total expected holding and back-order costs. An approximate decomposition technique, which is based on repeated application of the solution of a simpler single-stage problem, is proposed. The performance of the approximate technique is compared to exact results in a numerical study.

In Chapter 15, Yıldırım, Tan, and Karaesmen study a stochastic, multi-period production planning and sourcing problem of a manufacturer with a number of plants and subcontractors with different costs, lead times, and capacities. The demand for each product in each period is random. They present a methodology for deciding how much, when, and where to produce, and how much inventory to carry, given certain service level constraints. The randomness in demand and related probabilistic service level constraints are integrated in a deterministic mathematical program by adding a number of additional linear constraints. They evaluate the performance of their methodology analytically and numerically.

This volume is a reprint of a special issue of OR Spectrum (Vol. 27, Nos. 2–3) on stochastic models for the design, coordination, and control of

manufacturing systems, with the addition of Chapters 7 and 12 that appeared as articles in other issues of OR Spectrum. That special issue of OR Spectrum originated from the 4th Aegean International Conference on Analysis of Manufacturing Systems, which was held in Samos Island, Greece, in July 1–4 2003. The purpose of that issue was not to simply publish the proceedings of the conference. Rather it was to put together a select set of rigorously refereed articles, each focusing on a novel topic. Collected into a single issue the articles aimed to serve as a useful reference for manufacturing systems researchers and practitioners, and as reading materials for graduate courses and seminars.

We wish to thank Professor Dr. Hans-Otto Guenther, Managing Editor of OR Spectrum, and his staff for supporting the special issue of OR Spectrum and seeing that it becomes a published reality as well as for supporting its subsequent reprint into this volume with the addition of Chapters 7 and 12.

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