Stochastic Production Systems

Discrete Part Manufacturing Systems
Queuing Theory
Modeling
Stochastic

• *Random* (specifically, involving a random variable) or *probabilistic* (Merriam-Webster Dictionary)

• Random: According to M-W…
  – Lacking a definite plan, purpose, or pattern
  – Relating to, having, or being elements or events with definite probability of occurrence

• Why stochastic models?
  – Buzacott & Shanthikumar: because of the need to describe:
    • Disturbances: *to disturb* = *to throw into disorder, to make uneasy*
    • Variability: *variable* = *fickle, inconstant, aberrant*
      – Group characteristics may be known but next individual is a mystery
  – Unpredictability!!
Production

• Act or process of producing (manufacturing); the creation of utility; especially: the making of goods available for use

• Discrete Part Manufacturing (B&S)
  – Machines and work stations where operations are carried out on jobs (parts, items, subassemblies and assemblies) to create products that can be delivered to customers
  – Material handling and storage devices
  – Each item processed is distinct (not continuous processes)

• Also Services
  – Service industries account for 70 - 80 % of employment and 60 - 70 % of GDP in U.S.
  – “Job” can be any task to be carried out by a server in order to meet a customer’s need
  – Original context for most queuing models
Systems

• **M-W**: a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose

• **B&S**: Types of Discrete Part Manufacturing Systems
  – Job Shop: Large scope of products by variety of machines, flexible routings
  – Flow Line: Large volume by simplified material handling, standard sequence of operations
  – Transfer Line: May have synchronized movement of jobs
  – Flexible Machining System: Automated job shop
  – Flexible Assembly System: Automated movement to assembly, inspection and test
  – Cellular System: Each cell has specific capabilities, loose coupling among them
Queue

- **M-W:** A waiting line especially of persons or vehicles
  - Literally, tail (as of a beast)
    - View it as a symptom of inefficiency – the beast within
- In a manufacturing system, queue = inventory
  - waste, expense, not value-added, etc.
- In a service system, queue = poor service
- In a stochastic system, queues are unavoidable!
  - but they can be reduced if disturbances and variability are handled well and/or by adding to the capacity of the system
Performance Measures

• Production volume
  – Dollar value or total quantity per unit time
  – Correct mix of products is also important
  – Traditional criterion for low- and mid-level managers

• Quality
  – Extent to which the product meets customers’ expectations

• Customer service
  – Ability to meet promised delivery

• Cost
  – Test and inspection stations can improve quality
  – In-process inventory can increase volume and customer service
  – Main concern of upper management
Modeling Steps

1. Identify issues
   a) Time scale of decisions: strategic, tactical, operational
   b) Goals, performance measures, targets

2. Learn about the system

3. Choose a modeling approach
   a) Physical
   b) Computer (simulation)
   c) Analytical

4. Develop and test the model

5. Verify and validate the model
   a) Verify: Does it model what we think it models? Is it correct?
   b) Validate: Does it model the real system? Is it accurate?

6. Develop a model interface (decision support system)

7. Experiment with the model

8. Present the results
### Analytical vs. Simulation Models

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Analytical</th>
<th>Simulation</th>
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</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Try to include only most important aspects</td>
<td>Can be very complex and detailed (+/-)</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Easier to change but small changes may have big consequences</td>
<td>Hard to change once built</td>
</tr>
<tr>
<td>Data</td>
<td>Needs less</td>
<td>Needs more</td>
</tr>
<tr>
<td>Transparency</td>
<td>Clear to analyst, may be opaque to less well trained</td>
<td>Black box</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Effort to get tractable solution hard to estimate</td>
<td>Effort more “linear” and predictable</td>
</tr>
<tr>
<td>User interface</td>
<td>Needed for both!</td>
<td></td>
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</tbody>
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Chapter 1
Analytical vs. Simulation: Summary

• Both are important!
  – Use simulation to validate analytical approximations
  – Use analysis to determine where to focus simulation effort

• For stochastic systems, both will be descriptive not prescriptive
  – Analytical models usually easier to combine with optimization
  – Ideal: closed form expression for performance in terms of parameter(s) – can use calculus or search algorithm to optimize
  – Simulation-based optimization is a growing field

• What is the purpose of the model?
  – Understanding: Gain insight into how variable affects performance
  – Teaching: Help managers/workers understand what factors affect performance
  – Improvement: Explore changes in parameters and rules
  – Optimization: Find an optimal combination of parameters
  – Decision Making: How to design and/or operate the system
    • Discriminate effects of alternatives
    • Project their impact over time