Design and Operation of Manufacturing Systems

Manufacturing Systems Research at MIT

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Overview

- Manufacturing systems can be understood like any complex engineered system.

- Engineers must have intuition about these systems in order to design and operate them most effectively.

- Such intuition can be developed by studying the elements of the system and their interactions.

- Using intuition and appropriate design tools can have a big payoff.
Basic Issues

- Frequent new product introductions.
- Short product lifetimes.
- Short process lifetimes.

This leads to short factory lifetimes and frequent building and rebuilding of factories.

There is little time for improving the factory after it is built; it must be built right.
Basic Issues

- Tools to predict performance of proposed factory design.

- Tools for optimal real-time management (control) of factories.

- Manufacturing Systems Engineering professionals who *intuitively* understand factories as complex systems.
Basic Issues

Randomness and Uncertainty

- Factories are full of random events:
  - machine failures
  - changes in orders
  - quality failures
  - human variability

- The economic environment is uncertain:
  - demand variations
  - supplier unreliability
  - changes in costs and prices
Basic Issues

Therefore, factories should be

- designed and operated

to minimize the

- creation, propagation, or amplification

of uncertainty, variability, and randomness.
Factory Analysis and Design

- **Analysis**: given a proposed design, predict its performance.
  - production rate, inventory, lead time, quality, etc.
- **Design**: given a partial design, select specified items for best performance or profitability.
  - buffer sizes, machine selection.
• Start with small, simple, “toy” systems. Understand them thoroughly.

• Add features and complexity step by step to make our methods increasingly realistic and practical.
... also known as Production or Transfer Lines.

- Machines are unreliable, buffers are finite.

- **Issues:**
  - Machine failures propagate as disturbances when buffers become empty or full.
  - Large buffers reduce propagation but increase inventory.
  - System complexity makes performance prediction and analysis difficult.
Means, standard deviations, and percentiles of

- Production rate
- Inventory
- Lead time
- System yield, and other quality-related measures
Factory Analysis and Design

- Two-machine lines: production rate, inventory.
- Long lines by decomposition.
- Quality modeling and yield analysis.
Factory Analysis and Design

Five cases of two-machine lines:

Small buffers can increase production rate with small inventory costs; large buffers provide little benefit at great cost. Appropriate buffer size depends on the amount of variability.

$M_1, M_2$ average uptimes: 100; $M_2$ average downtime: 10; $M_1$ average downtimes: 16.7, 12.5, 10, .083, .071.

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• Decomposition breaks up systems and then reunites them.
• Conceptually: put an observer in a buffer, and tell him that he is in the buffer of a two-machine line.
• Question: What would the observer see, and how can he be convinced he is in a two-machine line? Construct the two-machine line. Construct all the two-machine lines.
Fast analytical tools for:

- performance evaluation of long flow lines, assembly/disassembly systems, systems with pallets, systems with various control policies;
- optimal allocation of buffer space;
- evaluating the interaction between buffer space and system yield.
Factory Analysis and Design

Solution

<table>
<thead>
<tr>
<th>Line</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>430</td>
</tr>
<tr>
<td>Case 2</td>
<td>485</td>
</tr>
<tr>
<td>Case 3</td>
<td>523</td>
</tr>
</tbody>
</table>

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Versions:

- The **Good** state has 100% yield and the **Bad** state has 0% yield.

- The **Good** state has high yield and the **Bad** state has low yield.
Factory Analysis and Design

Quality and Quantity

Buffer Size

Effective Production Rate

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Factory Operation

- Evaluate various policies by decomposition, including kanban, CONWIP, etc.

- Real-time scheduling of setup changes.
Industry Collaboration and Impacts

- HP (benefit in hundreds of millions of dollars)
- GM
- Peugeot
- ... and many others

Subjects: line design, performance evaluation, system quality analysis, material flow control, ...
Industry Collaborations and Impacts

Current Research

- Extension of performance evaluation to more general systems.
- Extension of optimization methods.
- Real-time scheduling of systems with setup costs.
- Quality in manufacturing systems.