Design and Operation of Manufacturing Systems

Manufacturing Systems Research at MIT

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July, 2008

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

Needs

- 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

- 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

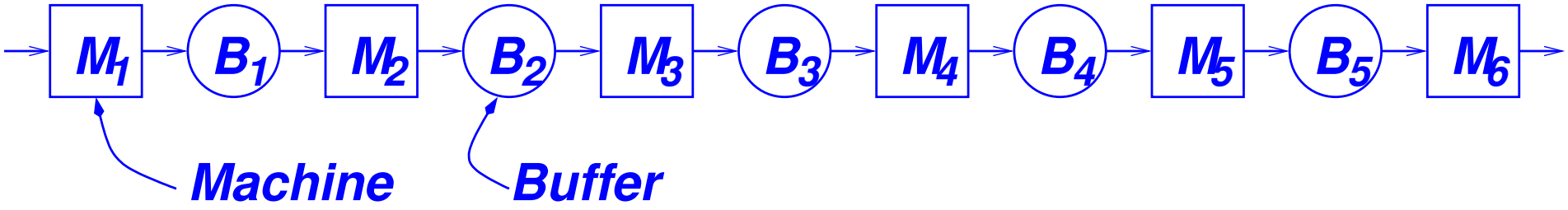
- *Analysis:* given a proposed design, predict its performance.
  - ⋆ production rate, inventory, lead time, quality, etc.
- *Design:* given a partial design, select specified items for best performance or profitability.
  - ⋆ buffer sizes, machine selection.

Research Approach

- Start with small, simple, “toy” systems. Understand them thoroughly.
- Add features and complexity step by step to make our methods increasingly realistic and practical.

Flow Lines

... 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.

Performance Measures

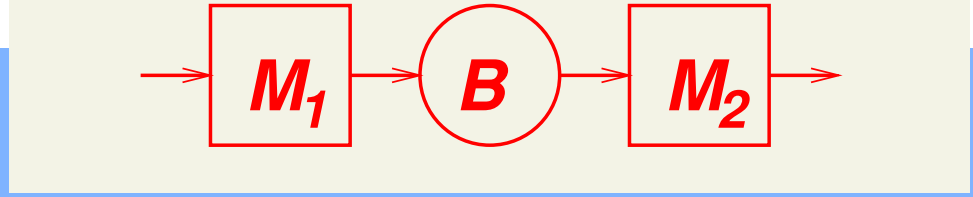
Means , *standard deviations* , and *percentiles* of

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

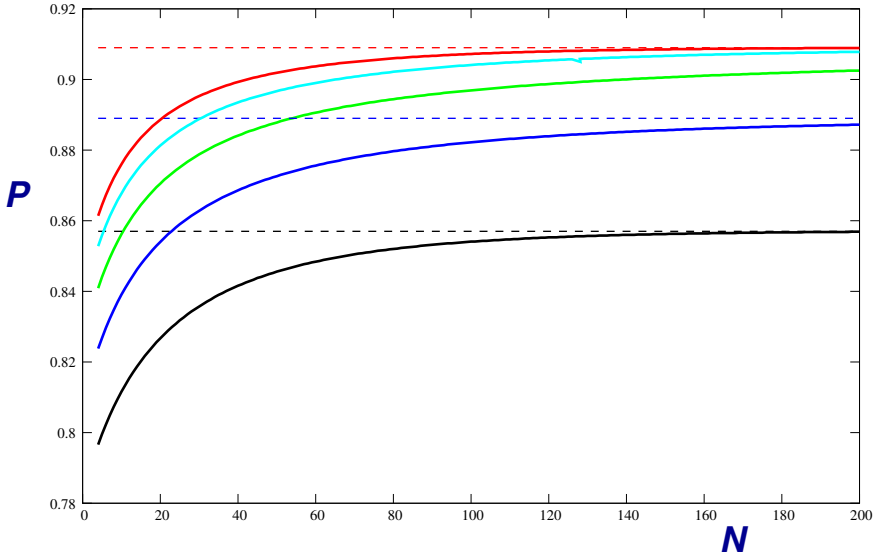
Methods

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

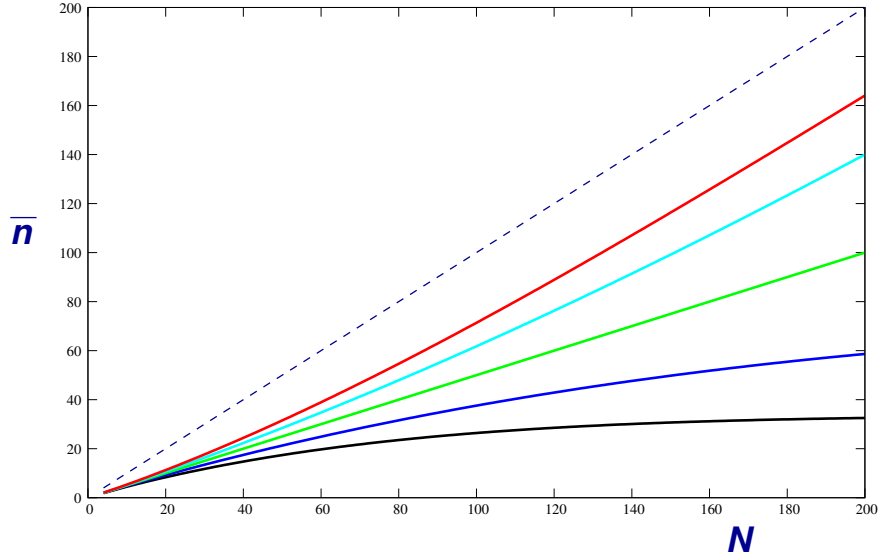
Factory Analysis and Design



Five cases of two-machine lines:



Production rate vs Buffer space

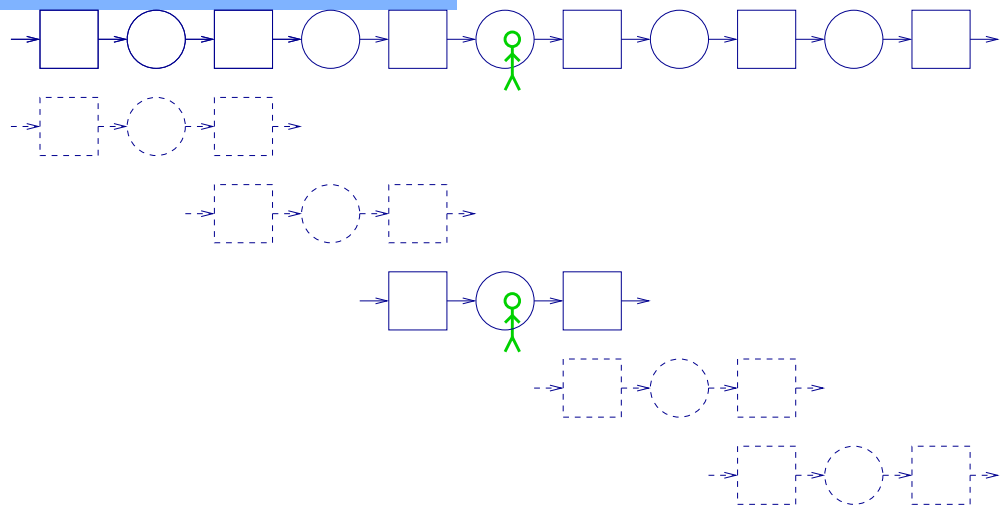


Average inventory vs Buffer space

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.

Decomposition



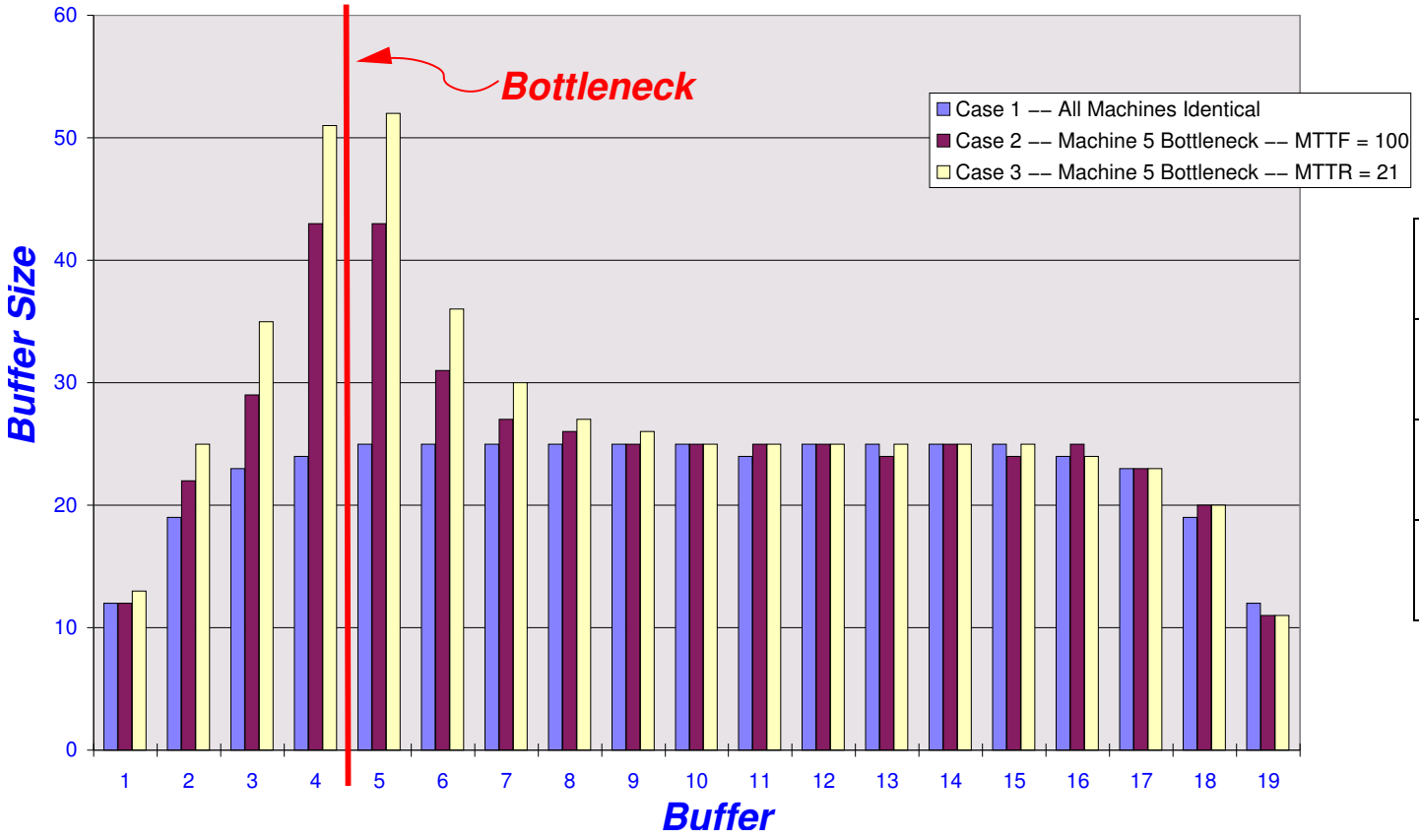
- Decomposition breaks up systems and then reunites them.
- Conceptually: put an observer in a buffer, and tell him that he is in the buffer of a two-machine line.
- Question: *What would the observer see, and how can he be convinced he is in a two-machine line?* *Construct the two-machine line. Construct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

Accomplishments

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.

Solution

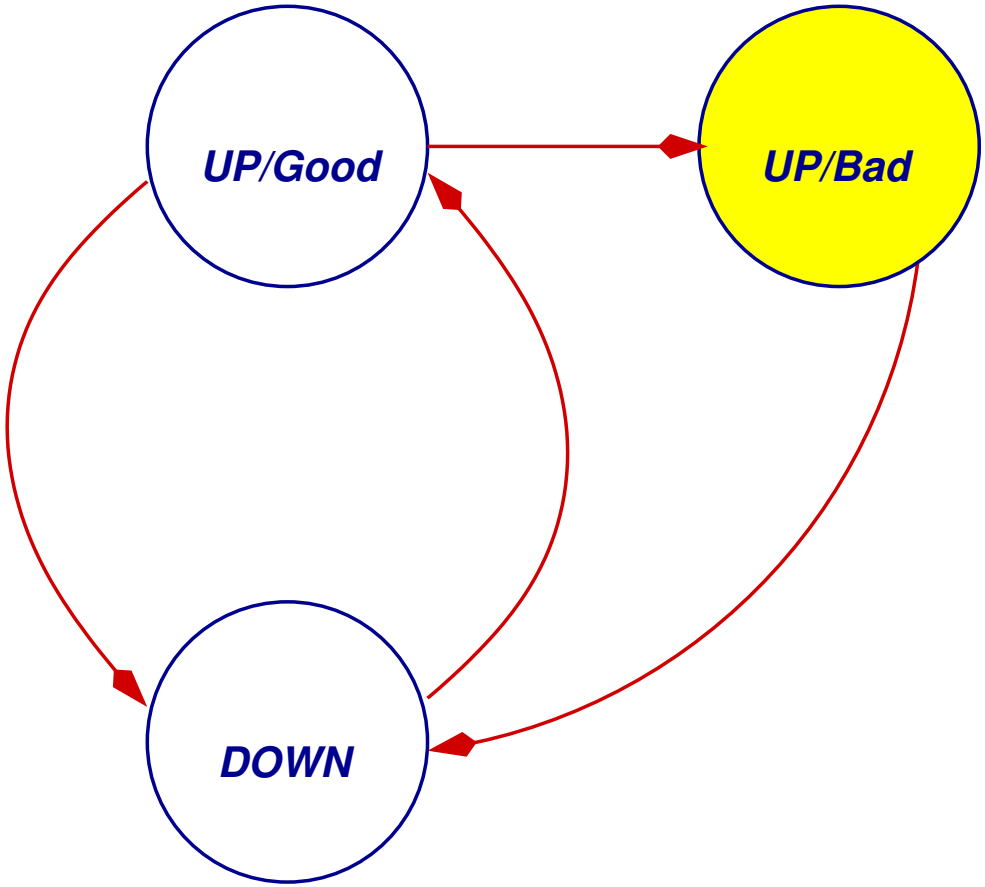


Line	Space
Case 1	430
Case 2	485
Case 3	523

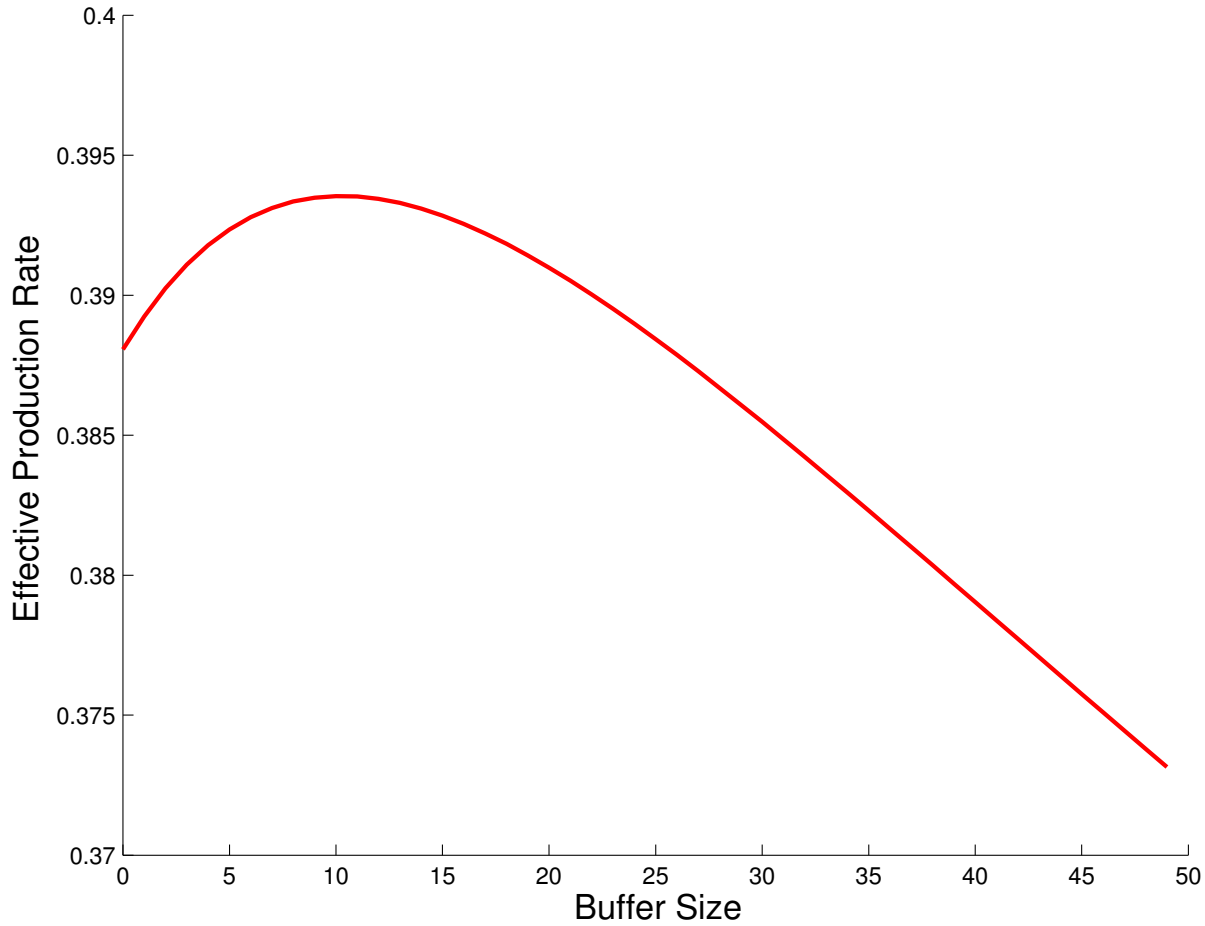
Quality and Quantity

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.



Quality and Quantity



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 Collaboration 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.