SMA 6304 / MIT 2.853 / MIT 2.854
Manufacturing Systems
Lecture 14: Manufacturing Systems Overview

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Goals

- To explain important measures of system performance.
- To show the importance of random, potentially disruptive events in factories.

Goals

- To give some intuition about behavior of these systems.
- To describe some current tools and methods.

Problems

- Manufacturing System Engineering (MSE) not as advanced as other branches of engineering.
- Practitioners encouraged to rely on gurus, slogans, and black boxes.
- Gap between theoreticians and practitioners.

Problems

- Research literature incomplete,
  - ⋆ ... but practitioners often unaware of what does exist.
- Terminology, notation, basic assumptions not standardized.
- Separation of product, process, and system design.

Problems

- Confusion about objectives:
  - ★ *maximize capacity?*
  - ★ *minimize capacity variability?*
  - ★ *maximize capacity utilization?*
  - ★ *minimize lead time?*
  - ★ *minimize lead time variability?*
  - ★ *maximize profit?*
- Systems issues are often studied last, if at all.

Problems

- Manufacturing gets no respect.
  - ⋆ *Systems not designed with engineering methods.*
  - ⋆ *Product designers and sales staff are not informed of manufacturing costs and constraints.*
- Black box thinking.
  - ⋆ *Factories not treated as systems to be analyzed and engineered.*
  - ⋆ *Simplistic ideas often used for management and design.*

Problems

Reliable systems intuition is lacking. As a consequence, there is ...

- Management by software
  - ⋆ *Managers buy software to make production decisions, rather than to aid in making decisions.*
- Management by slogan
  - ⋆ *Gurus provide simple solutions which sometimes work. Sometimes.*

Observation

- *When a system is not well understood, rules proliferate.*
- This is because rules are developed to regulate behavior.
- But the rules lead to unexpected, undesirable behavior. *(Why?)*

- New rules are developed to regulate the new behavior.
- Et cetera.

Observation

- A factory starts with one rule: *do the latest jobs first* .
- Over time, more and more jobs are later and later.
- A new rule is added: *treat the highest priority customers orders as though their due dates are two weeks earlier than they are.*
- The low priority customers find other suppliers, but the factory is still late.

- There are significant setup times from part family to part family. If setup times are not considered, changeovers will occur too often, and waste capacity.
- Any rules that that do not consider setup times in this factory will perform poorly.

Definitions

- *Manufacturing:* the transformation of material into something useful and portable.
- *Manufacturing System:* A manufacturing system is a set of machines, transportation elements, computers, storage buffers, people, and other items that are used together for manufacturing. These items are *resources.*

Definitions

- *Manufacturing System:*
  - ⋆ Alternate terms:
    - ∗ *Factory*
    - ∗ *Production system*
    - ∗ *Fabrication facility*
  - ⋆ Subsets of manufacturing systems, which are themselves systems, are sometimes called *cells, work centers,* or *work stations* .

Basic Issues

- Frequent new product introductions.
- Product lifetimes often short.
- Process lifetimes often short.

This leads to frequent building and rebuilding of factories.

Basic Issues

- Tools to predict performance of proposed factory design.
- Tools for optimal real-time management (control) of factories.
- Manufacturing Systems Engineering professionals who understand factories as complex systems.

- Quantity – how much and when.
- Quality – how well.

In this course, we focus on *quantity*.

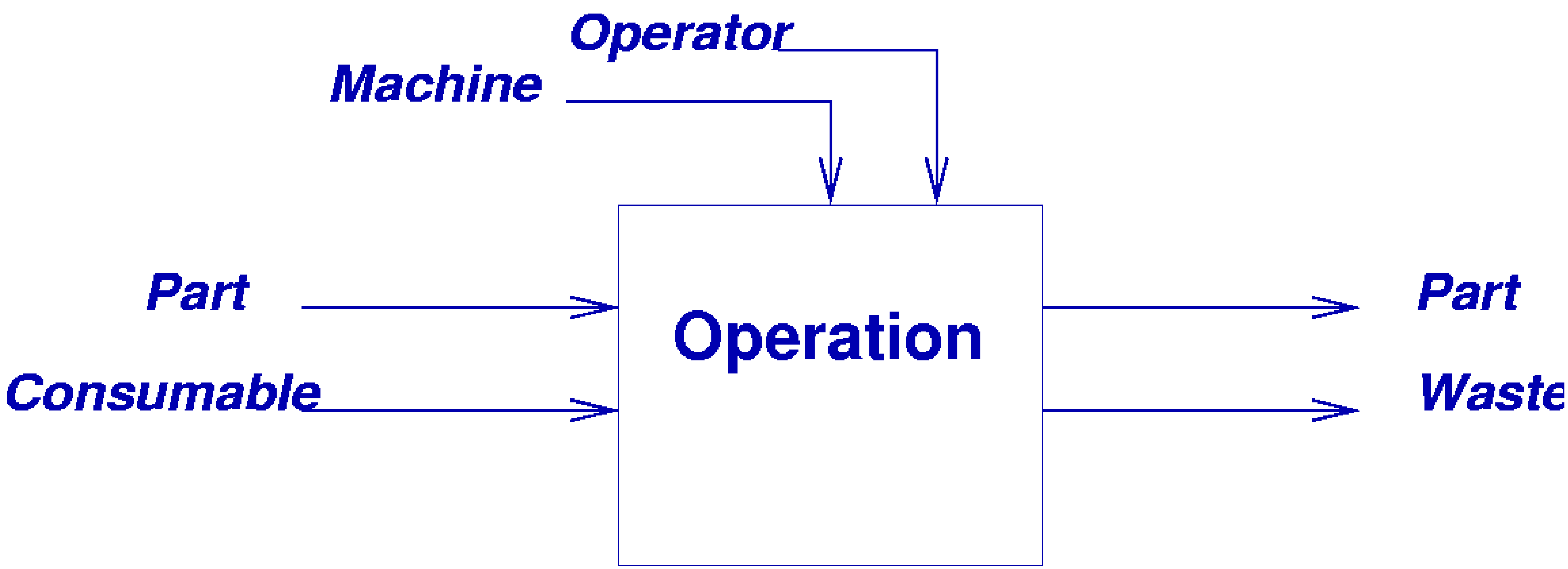
General Statement: Variability is the enemy of manufacturing.

Conflicting Objectives

- Make to Stock:
  - ⋆ items available when a customer arrives *(lots of inventory)*
  - ⋆ high profits and low prices *(little inventory)*
- Make to Order:
  - ⋆ early delivery promises *(unreliable promises or excess capacity)*
  - ⋆ reliable delivery promises *(late promises or excess capacity)*
  - ⋆ high profits and low prices *(no excess capacity)*

Basic Issues

- *Complexity:* collections of things have properties that are non-obvious functions of the properties of the things collected.
- *Non-synchronism (especially randomness) and its consequences:* Factories do not run like clockwork.



Nothing happens until <u>everything</u> is present.

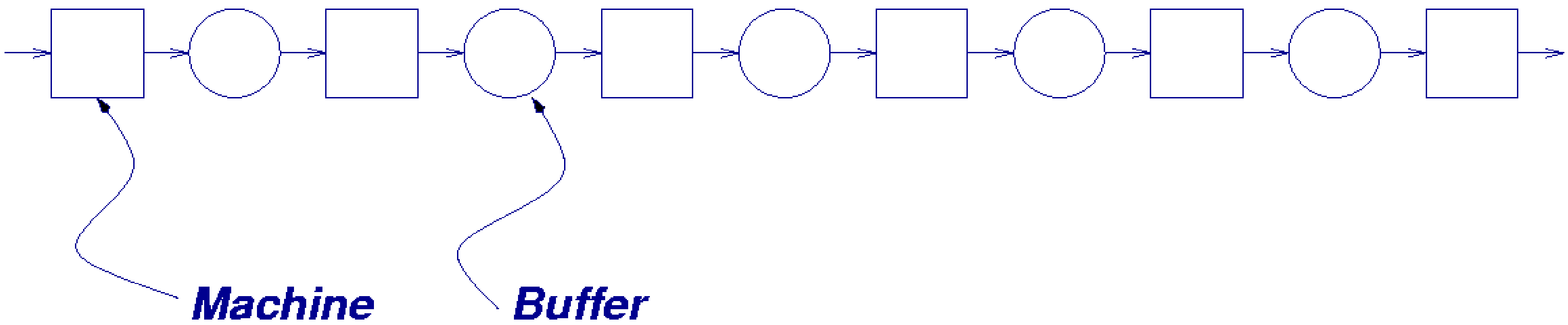
Whatever does not arrive last must wait.

- *Inventory:* parts waiting.
- *Under-utilization:* machines waiting.
- *Idle work force:* operators waiting.

Kinds of Systems

Flow shop

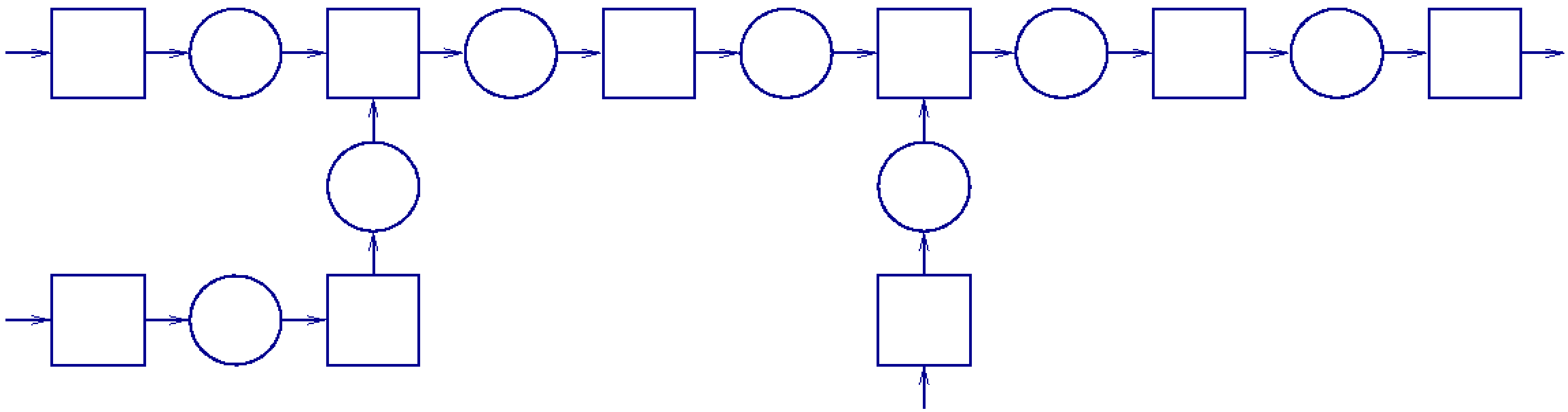
... or *Flow line* , *Transfer line* , or *Production line.*



Traditionally used for high volume, low variety production.

Kinds of Systems

Assembly system

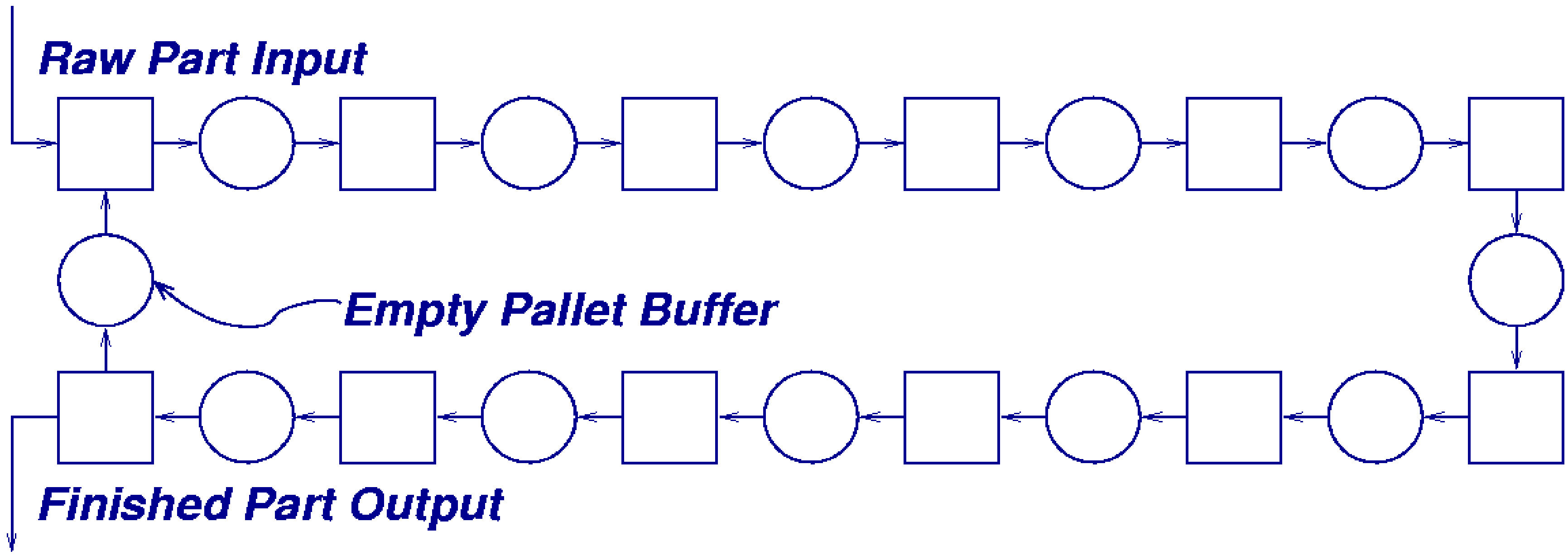


Assembly systems are *trees* , and may involve *thousands* of parts.

Kinds of Systems

Closed loop

Limited number of pallets or fixtures:

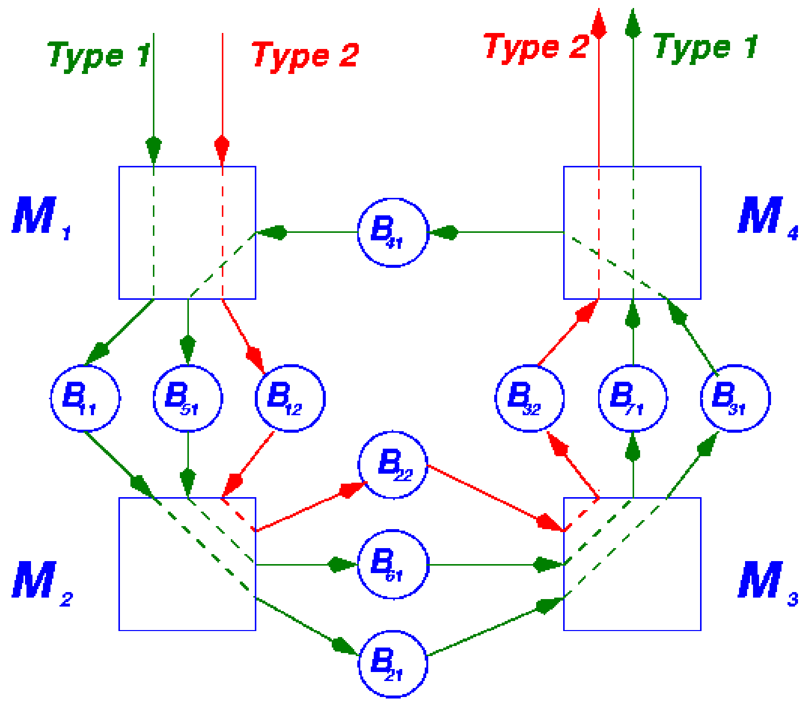


Pallets or fixtures travel in a closed loop.

Kinds of Systems

Reentrant

System with reentrant flow and two part types



Semiconductor fabrication is highly reentrant.

Kinds of Systems

Job shop

- Machines not organized according to process flow.
- Often, machines grouped by department:
  - ★ mill department
  - ★ lathe department
  - ★ etc.
- Great variety of products.
- Different products follow different paths.
- Complex management.

Two Issues

- Efficient design of systems;
- Efficient operation of systems after they are built.

Time

- All factory performance measures are about time.
  - ⋆ *production rate:* how much is made in a given time.
  - ⋆ *lead time:* how much time before delivery.
  - ⋆ *cycle time:* how much time a part spends in the factory.
  - ⋆ *delivery reliability:* how often a factory delivers on time.
  - ⋆ *capital pay-back period:* the time before the company get its investment back.

Time

- Time appears in two forms:
  - ★ delay
  - ★ capacity utilization
- Every action has impact on both.

Delay

- An operation that takes 10 minutes adds 10 minutes to the *delay* that
  - ★ a workpiece experiences while undergoing that operation;
  - ★ every other workpiece experiences that is waiting while the first is being processed.

Time

- An operation that takes 10 minutes takes up 10 minutes of the available time of
  - ★ a machine,
  - ★ an operator,
  - ★ or other resources.
- Since there are a limited number of minutes of each resource available, there are a limited number of operations that can be done.

Production Rate

- *Operation Time:* the time that a machine takes to do an operation.
- *Production Rate:* the average number of parts produced in a time unit. (Also called *throughput.*)

If nothing interesting ever happens (no failures, etc.),

$$\text{Production rate} = \frac{1}{\text{operation time}}$$

... but something interesting *always* happens.

Capacity

- *Capacity:* the maximum possible production rate of a manufacturing system, for systems that are making only one part type.
  - ⋆ *Short term capacity:* determined by the resources available right now.
  - ⋆ *Long term capacity:* determined by the average resource availability.
- Capacity is harder to define for systems making more than one part type. Since it is hard to define, it is *very* hard to calculate.

Randomness, Variability, 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

Randomness, Variability, Uncertainty

Therefore,

- factories should be designed as reliably as possible, to avoid creating variability;
- factories must be designed with *shock absorbers,* to reduce the propagation of variability;
- factories must be operated in a way that minimizes the creation of variability;
- factories must be operated in a way that minimizes the propagation of variability.

Randomness, Variability, Uncertainty

- Therefore, all engineers should know probability...
  - ⋆ *especially manufacturing systems engineers* .