

SMA 6304
Factory Planning and Scheduling
Lecture 15: Overview

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

- 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.

Observation

Why?

- 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 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.

Basic Issues

- Make to Stock:

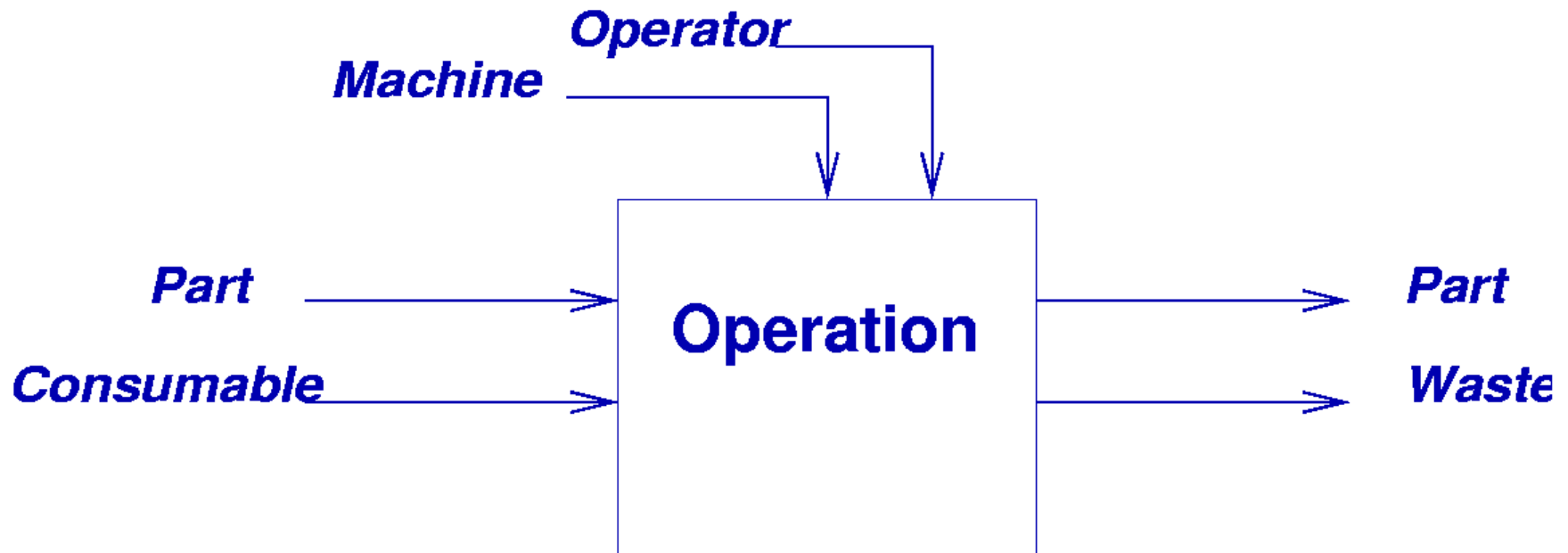
- ★ items available when a customer arrives (*lots of inventory*)
- ★ high profits and low prices (*little inventory*)

- 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.

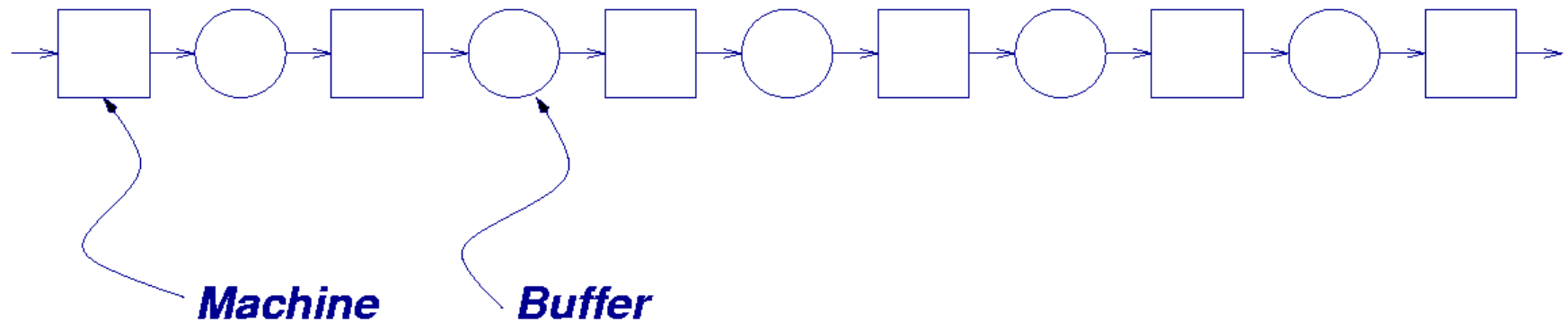


Nothing happens until everything is present.

Whatever does not arrive last must wait.

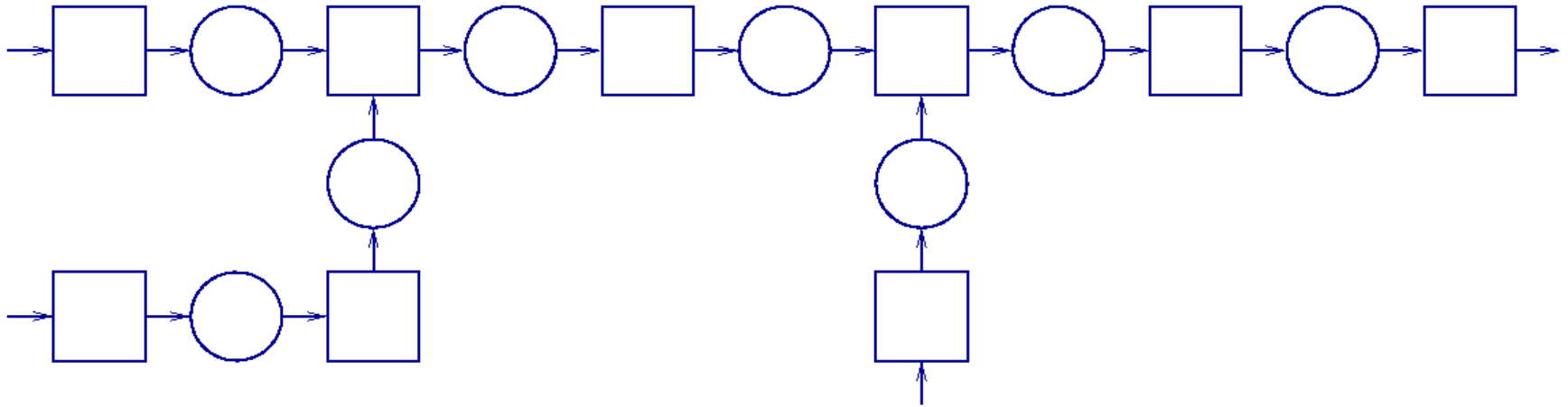
- *Inventory:* parts waiting.
- *Under-utilization:* machines waiting.
- *Idle work force:* operators waiting.

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



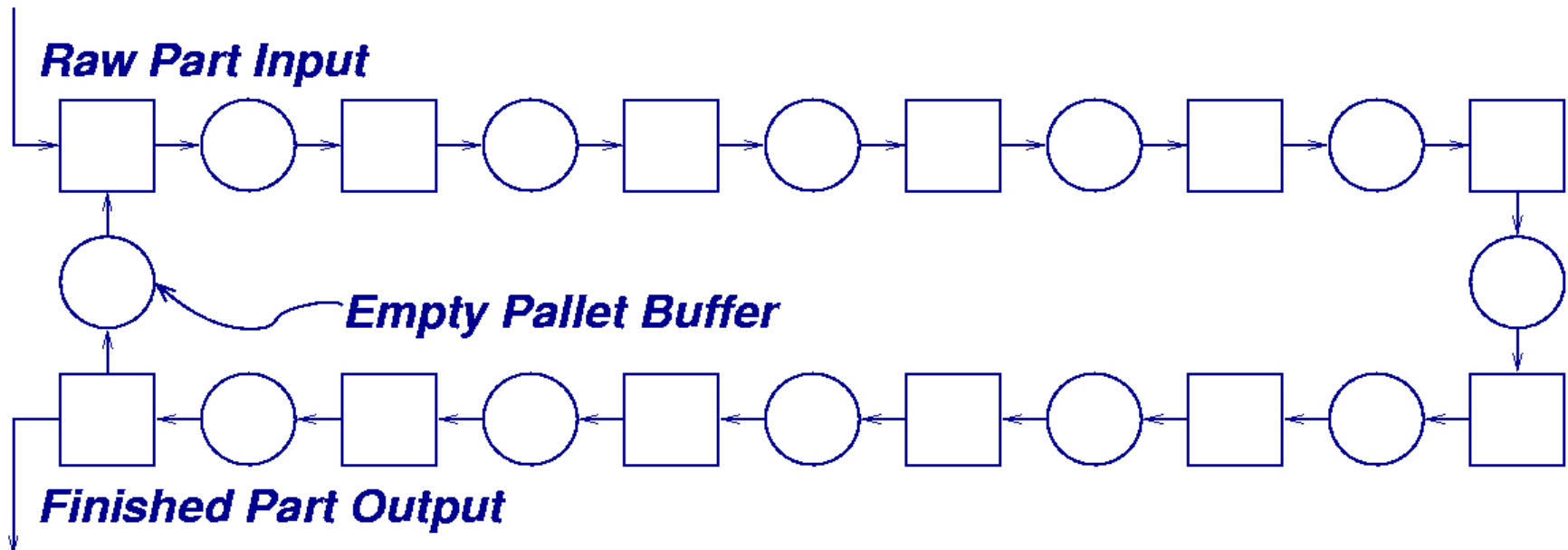
Traditionally used for high volume, low variety production.

Assembly system



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

Limited number of pallets or fixtures:

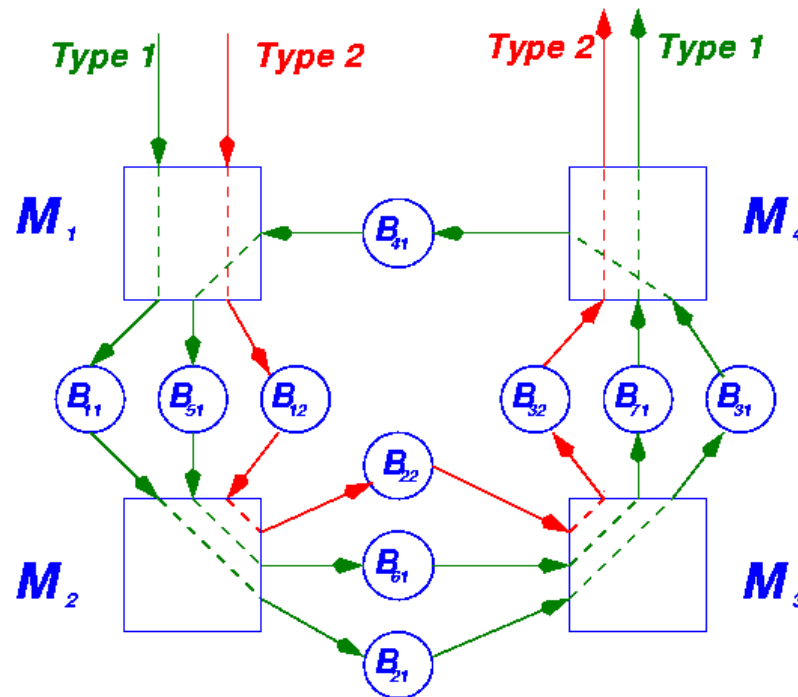


Pallets or fixtures travel in a closed loop.

Kinds of Systems

Reentrant

System with reentrant flow and two part types



Semiconductor fabrication is highly reentrant.

- 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.

- 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.

- 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.

- *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*: 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.

- 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

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.

- Therefore, all engineers should know probability...
 - ★ *especially manufacturing systems engineers* .
- Note: probability is not the same as statistics.