MIT 2.853/2.854

Introduction to Manufacturing Systems

Manufacturing Systems Overview

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HP Printer Case

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- Hewlett Packard was designing and producing its printers in Vancouver, Washington (near Portland, Oregon).

HP Printer Case

HP's needs

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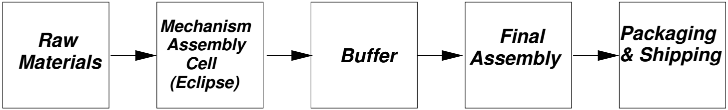
- Meet profit and revenue targets.
- Keep employment stable.

HP Printer Case

Printer Production

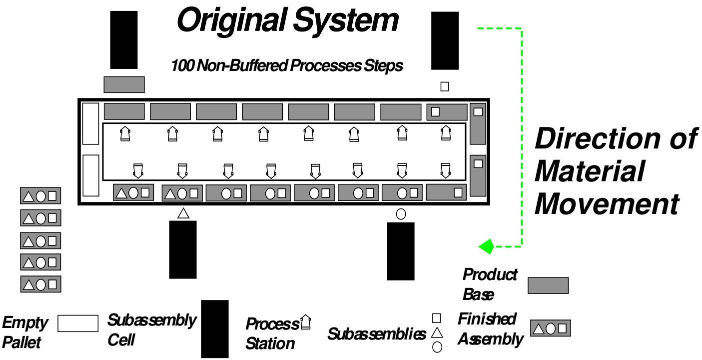
HP invested $25,000,000 in "Eclipse," a new system for automated assembly of the print engine.

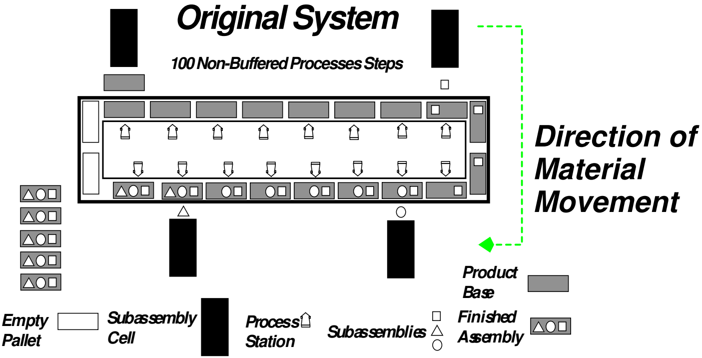


Two Eclipses were installed.

HP Printer Case

Printer Production





Design philosophy: minimal — essentially zero — buffer space.

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Actual production rate would be about 125,000 units/month.

---

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- Infeasible changes: adding labor, redesigning machines.

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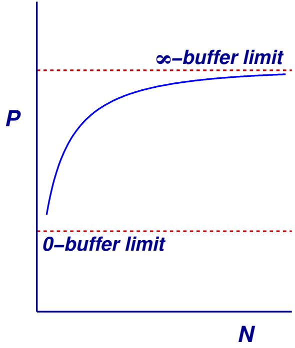

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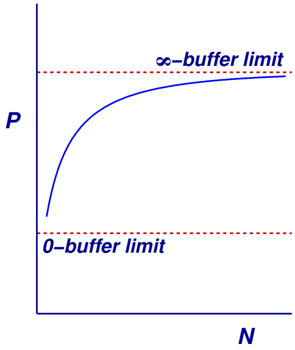

- Design and analysis tools: *described in the second part of this course.*

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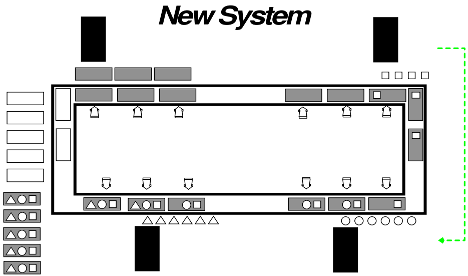

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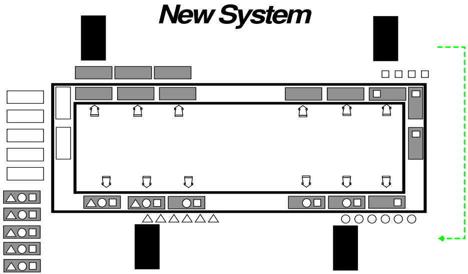

- Empty pallet buffer.

HP Printer Case

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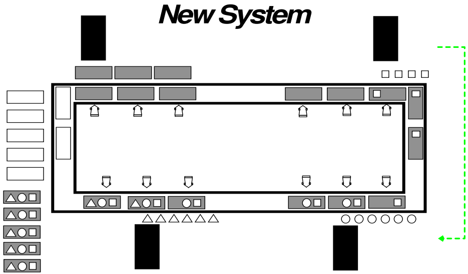

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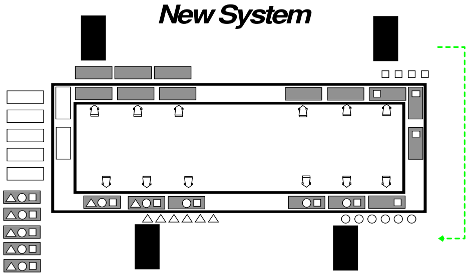

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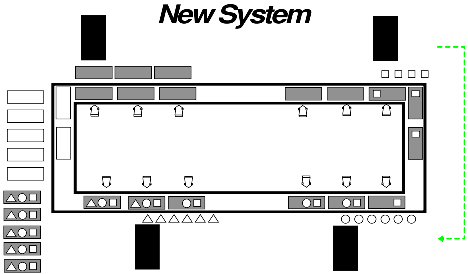

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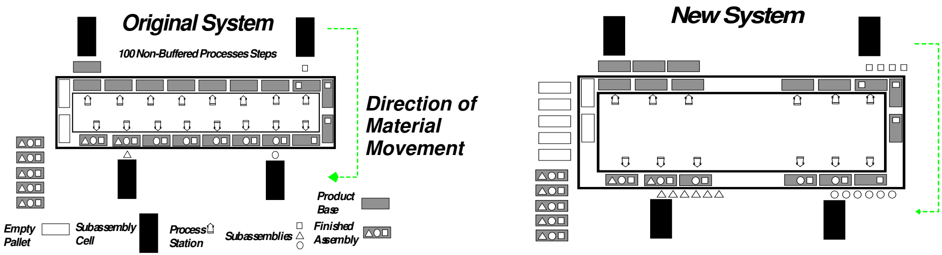
- Buffer sizes were large enough to hold about 30 minutes worth of material. This is a small multiple of the mean time to repair (MTTR) of the machines.

HP Printer Case

Comparison



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- Labor productivity increased by about 50%.

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Course Overview

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- 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.

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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 and justify some quantitative tools and methods.
- But *not* to describe all current common-sense approaches.

Approach

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- A gap exists between theoreticians and practitioners.

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  - ⋆ They should be done simultaneously or iteratively, *not* sequentially.

Problems

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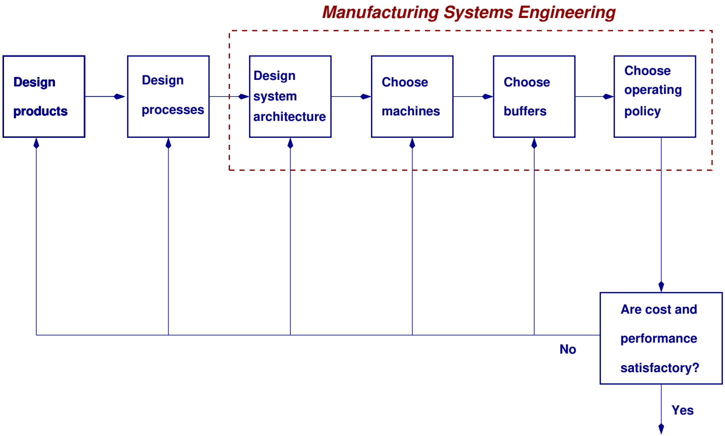
Product Realization

Products, Processes, Machines, Buffers,and Operating Policy



Rule proliferation

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- Et cetera.

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- *Why?*

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- Any rules that do not consider setup times in this factory will perform poorly.

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- Subsets of manufacturing systems, which are themselves systems, are sometimes called *cells, work centers,* or *work stations* .

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

Basic Issues
Consequent Needs

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Basic Issues

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Consequent Needs

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

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- Design Quality – the design of products that give customers what they want or would like to have *(features)*.
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This course is about manufacturing, *not* product design.

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General Statement: Variability is the enemy of manufacturing.

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  - items available when a customer arrives

Basic Issues

Styles for Demand Satisfaction

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- Make to Order:
  - ⋆ production started only after order arrives
  - ⋆ appropriate for custom products, low volumes, expensive raw materials

Basic Issues

Conflicting Objectives

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Conflicting Objectives

- Make to Order:
  - ⋆ excess production capacity *(low utilization)* needed to allow early, reliable delivery promises
  - ⋆ minimal production capacity *(high utilization)* needed to to keep costs low

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Basic Issues

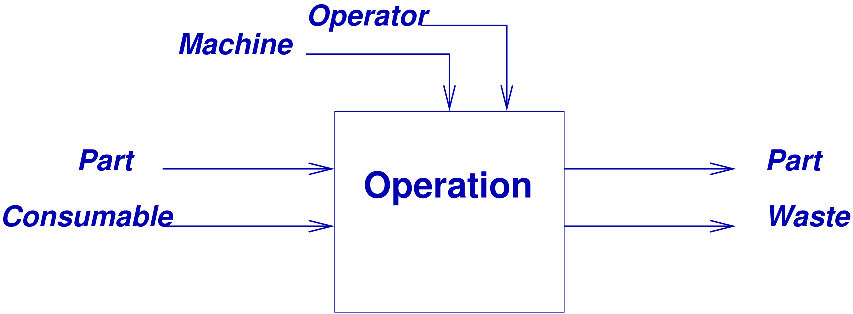
Concepts

- *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.

Basic Issues

Operation



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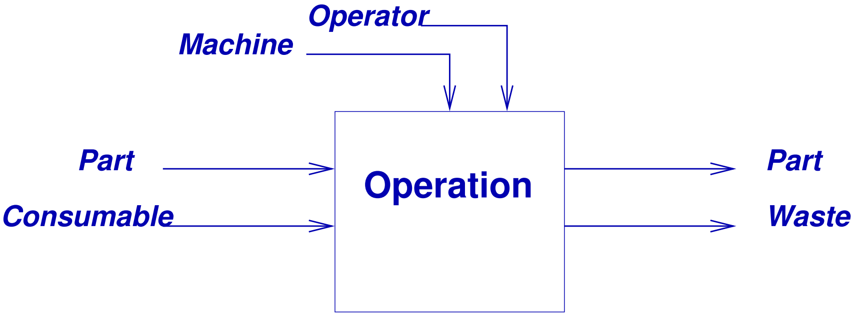

Nothing happens until <u>everything</u> is present.

Whatever does not arrive last must wait.

Basic Issues
Waiting

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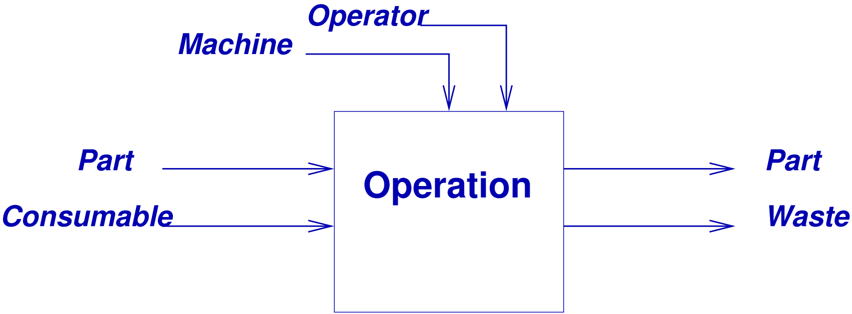
- *Idle work force:* operators waiting.

Basic Issues

Waiting



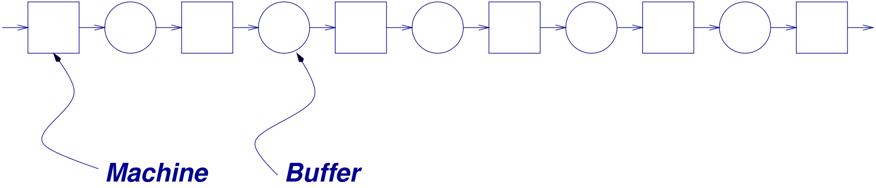
- *Reductions* in the availability, or ...
- *Increased variability* in the availability ...

... of any one of these items increases waiting in the rest of them and reduces performance of the system.

Kinds of Systems

Flow shop

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



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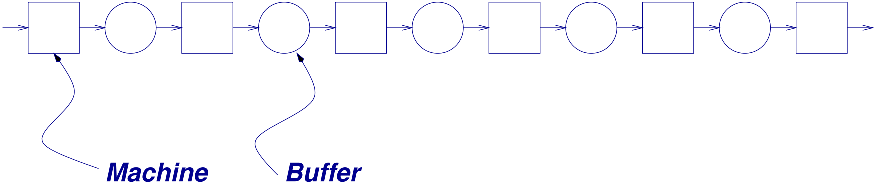
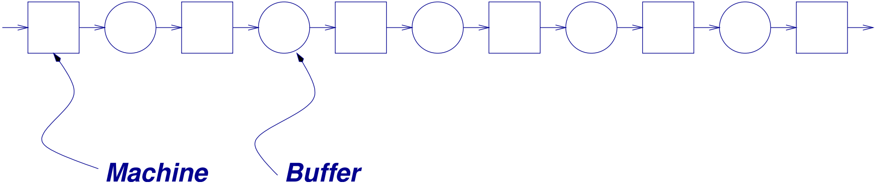


Traditionally used for high volume, low variety production.

Kinds of Systems

Flow shop

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

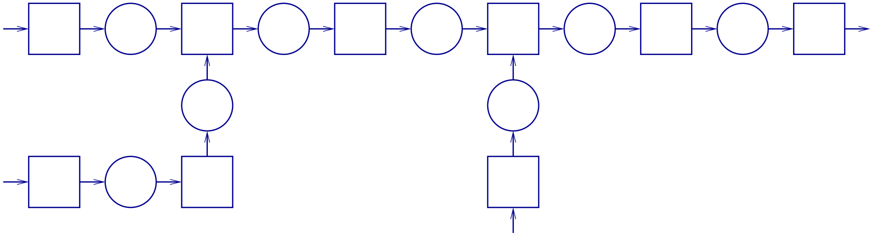


Traditionally used for high volume, low variety production.

What are the buffers for?

Kinds of Systems

Assembly system

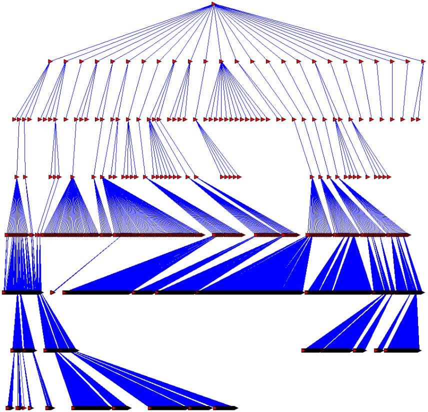


Assembly systems are *trees* , and may involve *thousands* of parts.

Kinds of Systems

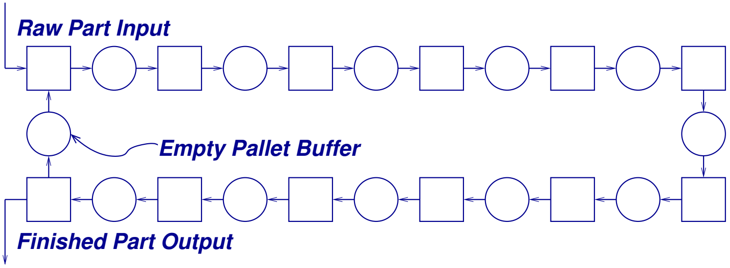
Assembly system

Bill of Materials of a large electronic product



Kinds of Systems — Loops

Closed loop *(1)*



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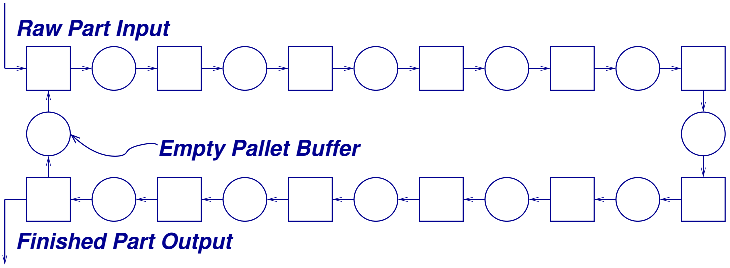
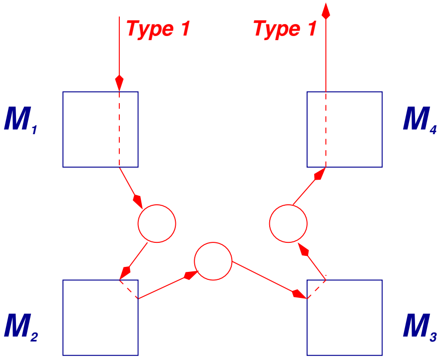


Pallets or fixtures travel in a closed loop. Routes are determined. The number of pallets in the loop is constant.

Kinds of Systems — Loops

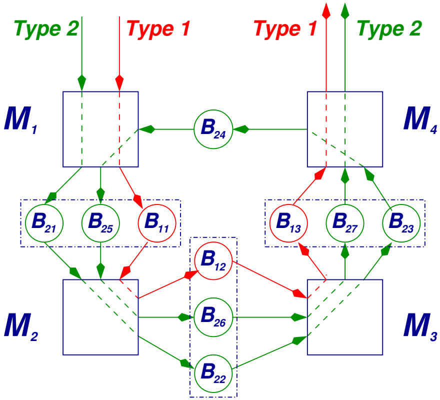
Reentrant loops *(2)*



Kinds of Systems — Loops

Reentrant loops *(2)*

System with reentrant flow and two part types



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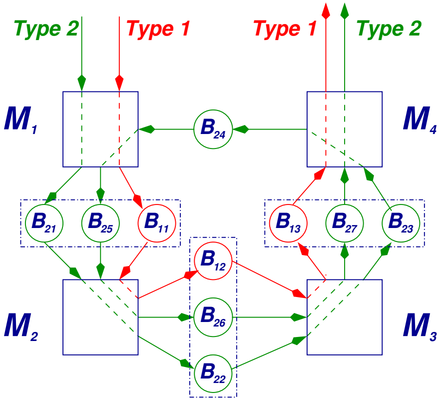

Routes are determined. The number of parts in the loop varies.

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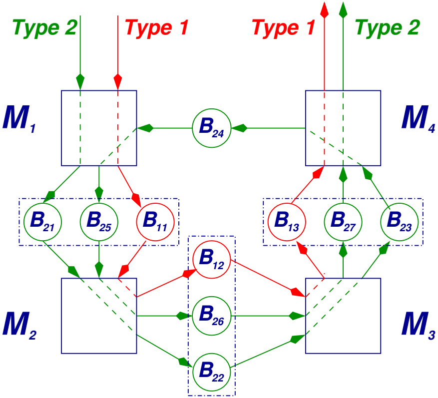

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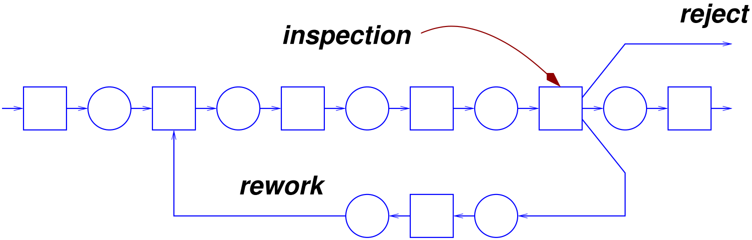
Semiconductor fabrication is highly reentrant.

Kinds of Systems — Loops

Rework loop *(3)*



Routes are random. The number of parts in the loop varies.

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  - *capital pay-back period:* the time before the company get its investment back.

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"customer demand could consume all our inventory in x weeks."

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- Every action has impact on both.

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- The sum of all the delays that a part experiences during production is the extra time that a part spends in a factory beyond the time required for its operations.
  - ⋆ That is often between 10 and 100 times the total operation time.

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- In other words, this is the limit on the factory's production rate.

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... but something interesting *always* happens.

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- 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.

Two Issues

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- *Randomness:* A specific kind of incomplete knowledge that can be quantified and for which there is a mathematical theory.

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of *uncertainty*, *variability*, and *randomness*.

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  - ⋆ Simulation models, in which a computer program is created to mimic the events in the system to be analyzed. They are widely used in industry. Generating numbers is easy, but generating meaningful numbers is not so easy.

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- Most of our models will be mathematical, but this is not a math course!!

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7. ***Manufacturing systems intuition must include intuition about variability, uncertainty, and randomness.***