Systems Modelling and Simulation (6)

Manufacturing Systems

Further Essential Reading:

1. R. G. Askin and C. R. Standridge (1993); Modelling and Analysis of Manufacturing Systems; John Wiley & Sons, Inc.
2. M. P. Groover (2001); Automation, Production Systems, and Computer Integrated Manufacturing; Second Edition; International Edition; Prentice Hall International, Inc.

Today’s discussions

- Manufacturing Systems
- Components of Manufacturing Systems
- Principles of Manufacturing Systems
- Types of Manufacturing Systems
- Overview of Classification Scheme
  - **Single Station**
  - **Multi-Station**
  - **Production Line**

Manufacturing Systems

A set of integrated resources (machinery, labourer, equipment, information, and tools) that process raw material as input and produce final products as outputs.

Its Purpose:

1. Meet customer requirements
2. Add Value
3. At Minimum cost
4. High Quality and Reliable
5. Environmentally Friendly

Manufacturing Systems Management

The responsibilities of management are:

- Establish priorities
- Utilise resources
- Monitor Performance
- Measure Performance
- Improve productivity (yield) and efficiency (input/output)

Component of Manufacturing Systems

1. Production Machines, tools, fixtures, and other hardware equipment
2. Material Handling Systems
   - **Loading and unloading (batch control)**
   - **Positioning (manual, automated)**
   - **Transporting (conveyors, transporters)**
   - **Temporary storage (buffers)**
3. Computer Control Systems (SCADA, Robotics, Scheduling, Safety Monitoring, Quality, …)
4. Human Resources

Basis for classification of Manufacturing Systems (Groover 2001)

1. Types of operations
2. Number of workstations and system layout
3. Product variety
4. Level of automation

1. Types of operations

- **<u>Processing operations</u>**: Working on individual parts (e.g. metal sheets, rolling, machining, drilling, treating, painting, etc.)

- **<u>Assembly operations</u>:** combining and putting parts together e.g. (mounting gearbox, engines dressing, Trimming shops in car factories, etc.)

- **<u>Type of parts and products</u>:** The specification of the material and also the method of processing the part

2. Number of Workstations *(n)* and System Layout

- **Key factor** in classification scheme
- Determines main **performance factors** such as capacity, capability, efficiency, productivity, utilisation, cost per unit, and maintainability
- Determines the **complexity** of operations
- Arrangement of workstations is called **System Layout**

2.1 Three levels of classification

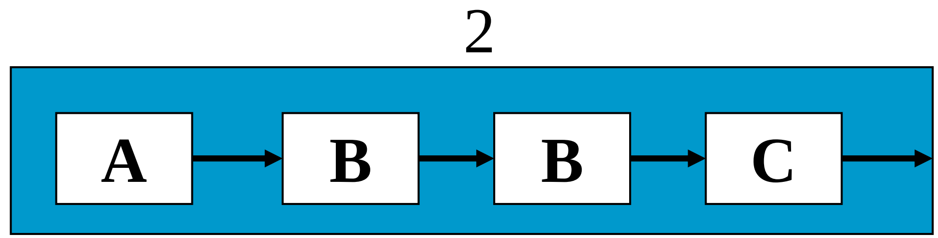
Type I: Single Station where ***(n = 1)***

Type II: Multiple Stations with fixed routings where ***(n > 1)***

Type III: Multiple Stations with variable routing where ***(n >1)***

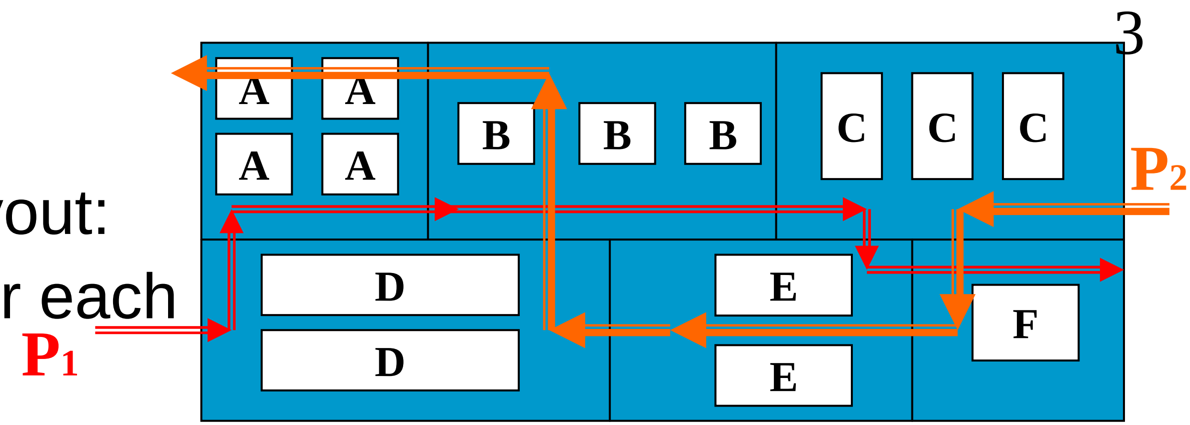
2.2 Type of System Layout (Askin et al 1993)

1. Fixed Position
2. Product Layout

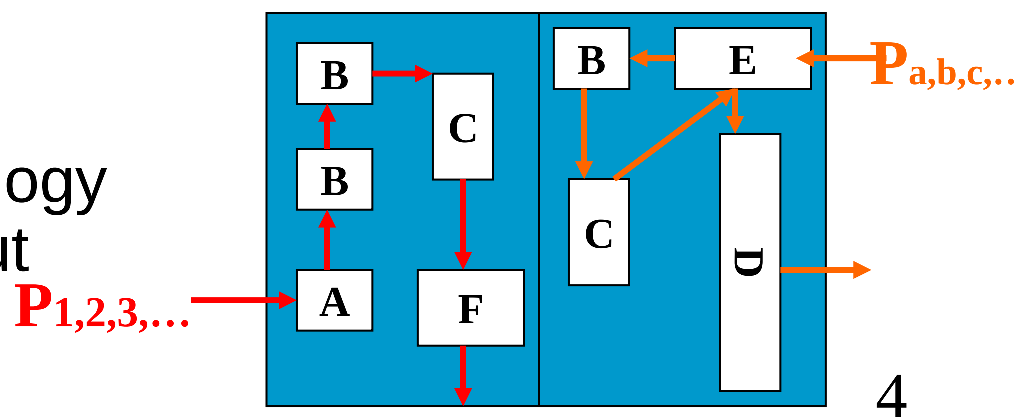


3. Process Layout:

(unique path for each product)



4. Group Technology (Cellular) layout



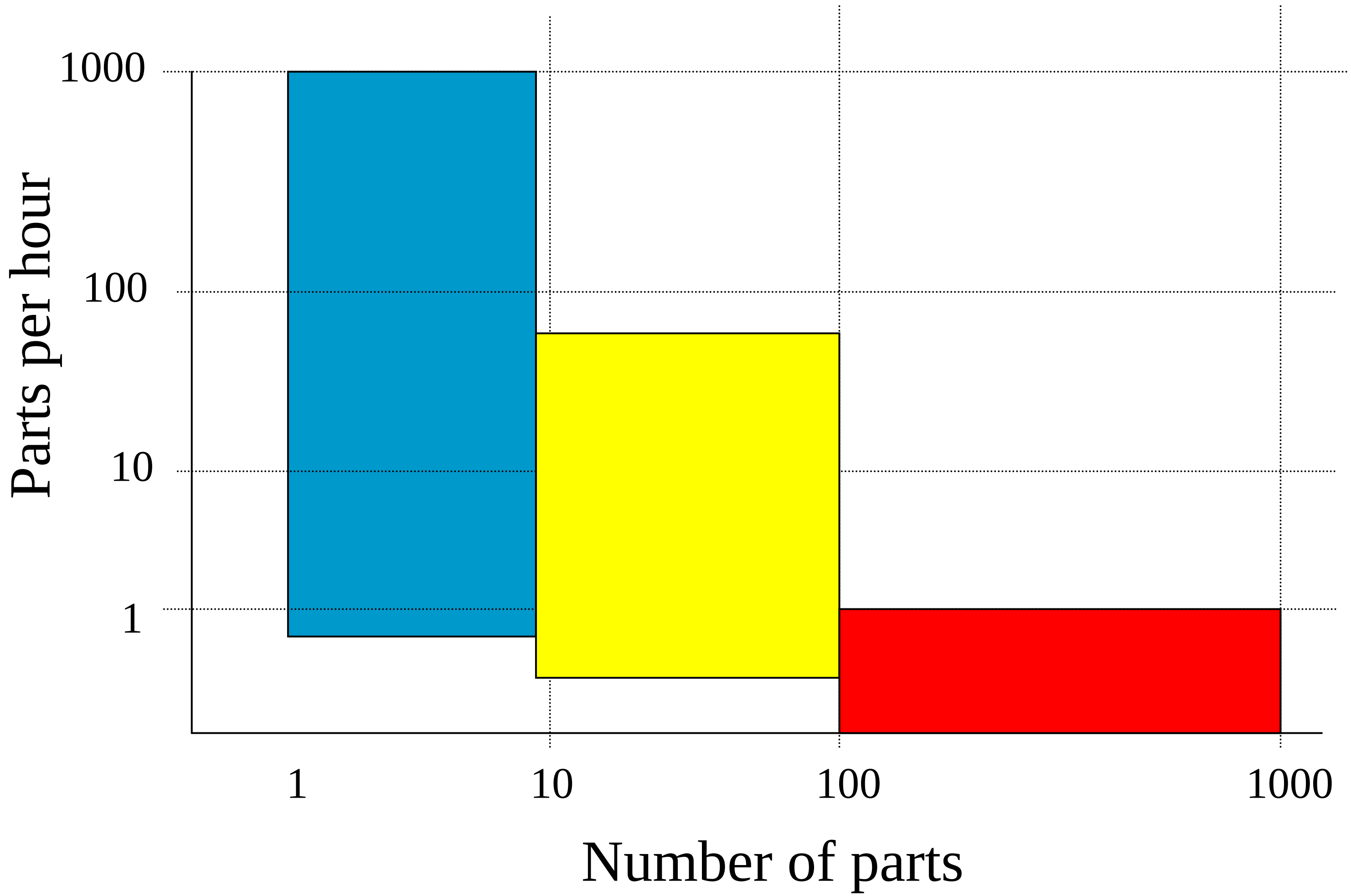
Characteristics of Layout Types

(Askin et al 1993)

Characteristics	Product	Process	Group (Cell)	Fixed Pos.
Throughput time	Low	High	Low	Medium
WIP	Low	High	Low	Medium
Skill Levels	Choice	High	Med-High	Mixed
Product Flexibility	Low	High	Med-High	High
Demand Flexibility	Medium	High	Medium	Medium
Machine Utilisation	High	Med-Low	Med-High	Medium
Operator Utilisation	High	High	High	Medium
Production cost/unit	Low	High	Low	High

3. Product Volume vs. Variety

(Askin et al 1993)



4. Level of Automation

A manufacturing system can be manually operated, semi-automated or automated.

Manning Level: Is the portion of time that a direct labour must be in attendance. Example:

If $M_i = 1$ means 1 man attends station *i* at all times

If $M_i = 0.25$ means 1 man attends 4 machines at all times

If $M_i = 4$ means …

$$M = \frac{w_u + \sum_{i=1}^{n} w_i}{n} = \frac{w}{n}$$

No. Utility

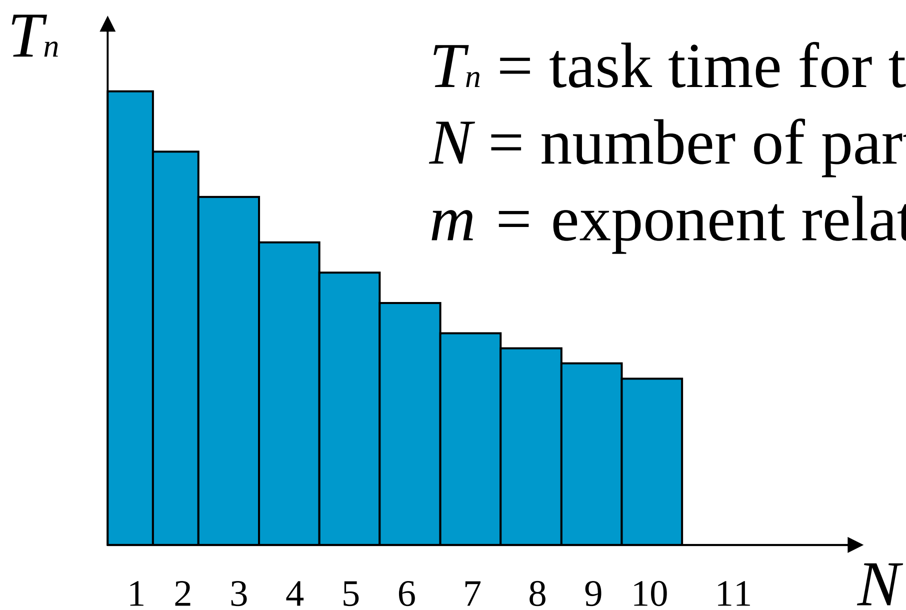
No. workers at station i

No. stations

Time Analysis – Manufacturing Progress Functions (Learning Curve)

Processes that require manual intervention and manual work:

Learning curve phenomenon for a learning rate of 80%



T_n = task time for the N$_{th}$ work

N = number of parts in the series

m = exponent related to learning rate

$$T_N = T_1 (N)^m$$

$$m = \frac{\ln(LearningRate)}{\ln(2)}$$

Example

Typical Learning Rates (Groover 2001)	
Assembly, electrical harness	85%
Assembly Electrical	85%
Assembly Mechanical	84%
Assembly Prototypes	65%
Inspection	92%
Machining	90%
Sheet metal working	90%
Welding	85%

T_1 = 3.8 min.

Learning Rate = 92%

T_{50} = ?

T_{500} = ?

Solution:

$$m = \ln(0.92)/\ln(2) = -0.1203$$

$$T_{50} = 3.8(50)^{-0.1203} = 2.37 \text{ min.}$$

$$T_{500} = 3.8\,(500)^{-0.1203} = 1.8 \text{ min.}$$

Principles of Manufacturing Systems

First Law (Little's Law): in a steady state system

WIP = Production Rate x Throughput Time

Production rate = ***X***

Number of parts = ***N***

Throughput Time = ***T***

Therefore: ***N = XT***

Principles of Manufacturing Systems cont.

Second Law: Matter is conserved

Raw material enter the system (input) and finished products exit the system (output). Any remaining or rejected parts need to be accounted for. Therefore the summation of entry should be equal:

Total Material Entry (input) = Finished Parts (output) + Removed Material + Disposed Material + Recycled Material

Principles of Manufacturing Systems cont.

Third Law: The larger the system the less reliable it is

Reliability theory says that if we have ***N*** statistically independent components in a system with reliability value of $\boldsymbol{r_i}$ then the reliability of the system (probability of availability) would be:

$$\prod_{i=1}^{N} r_i = r_1 \times r_2 \times ... \times r_N$$

Principles of Manufacturing Systems cont.

Fourth Law: Objects decay

Both hardware and software objects decay over time, they need maintenance and replacement

Fifth Law: Exponential growth in complexity

Complexity increases with a larger rate when components are added to the system.

For example: *M* components that can be in *N* states the system could be in: N^M

Principles of Manufacturing Systems cont.

Sixth Law: Technology advances

Natural evolution to better material, processes and information

Seventh Law: System components appear to behave randomly

Events can not be precisely predicted, by nature events or stochastic and this needs to be heeded in any system design, development and analysis

Principles of Manufacturing Systems cont.

Eighth Law: Limits of human rationality

Human beings have limitations, this should be accounted for in any system analysis

Ninth Law: Combining, Simplifying, and Eliminating save Time, Money and Effort

KISS concept – Good models are abstract, straight to the point, accurate and specified objectives.

"Over complication is Lethal"

Finally

- Manufacturing Systems
- Components
- Types
- Rules that govern