# Systems Modelling and Simulation (7)

## Type I Single Station System and Type II Group Technology (Cellular Systems)

Further Essential Reading:

1. M. P. Groover (2001); Automation, Production Systems, and Computer Integrated Manufacturing; Second Edition; International Edition; Prentice Hall International, Inc.

# The remaining subjects

1. Type I and Type II Systems
2. Manual Assembly Line
3. Layout Design
4. Queuing Theory

# Today’s discussions

- Single station manned and automated cells
- Applications of the two system types
- Analysis of single station cells
- **Group technology and cellular manufacturing**
  - **Parts analysis**
  - **Production flow analysis**
  - **Applications**
- Preliminary Plant layout using Precedence (From-To) Charts

# Single station manufacturing system **(applicable to all systems)**

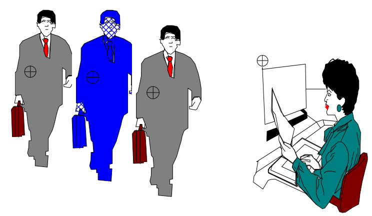
- Are independent units within a layout
- Manufacture, assemble or provide service independent from other resources
- Designed for single product, batch, or mixed-model (different parts made sequentially)
- Manned or Automated cells

# Manned Cells & Automated Cells

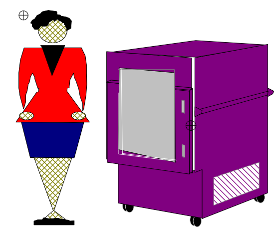
- Manned:
  - **One operator responsible for a task either using a specific machine, tools, computer, telephone, …**
  - **Simplest to set up and run with minimal capital expenditure**
  - **May require high skilled operators**
- Automated
  - **A single machine handling parts/people etc. (example: CNC, robots, answering machines, computer servers, …**
  - **High production rates**

# Manned Cells & Automated Cells Examples

***Passengers***



Manual Check-in



Automatic Check-in

# Analysis of single station system

1. Number of workstations needed

2. Machine Clusters

# Number of workstations required

Design for specified quantity of products at a specified production rate.

**To determine the number of workstations based on that specification.**

$$n = \frac{WL}{AT}$$

$$WL = Q\,T_c \quad or \quad WL = \sum_j Q_j T_{cj}$$

*N = number of workstations* *AT = Available time in a station*

*WL = worlkload for a given period*

*Q = Quantity to be produced for that period*

*$T_c$ = cycle time required for each piece (time to make)*

*j = product type*

*$Q_j$ = Quantity of product j*

*$T_{cj}$ = cycle time for product j*

# Example

- Total of 1000 parts needs to be produced in a week, each part is identical and requires a milling machine, each part requires 12.5 min. to be produced.
- It takes 2.5 hrs to setup each machine (0.5 per day / 5 days week, total hours available in a week is 40 hrs.
- How many Milling Machines are needed?

$$WL = 1000\,(12.5) = 12500 \ \ \textbf{min.} = 208.33\ \textbf{hrs.}$$

**Time Avaialble for a Milling machine in a Week :**

$$AT = 40 - 2.5 = 37.5\ \textbf{hrs.}$$

$$n = \frac{208.33}{37.5} = 5.55\ \textbf{Machine or 6 machines}$$

$$\textbf{Utlisation} = \frac{5.55}{6} = 0.925$$

# Machine Clusters

- Sometimes a machine does not require continuous attention from an operator, hence an operator can handle more than 1 machine
- Still considered as type I, because operator attention is required every work cycle
- Manning level from M = 1 to M = 1/n (n is number of machines assigned to a worker)
- A *machine cluster* is a combination of two or more machines that produce identical products or products with same cycle time

# Machine Clusters cont.

If:

$T_m$ is machine cycle time

$T_s$ to be the machine service time done by a worker

And provided that the machine is available at all times then:

*The total cycle time would be,*

$$T_c = T_m + T_s$$

*For a balanced system the number of machines that can be assigned to an operator would be:*

$$n = \frac{T_m + T_s}{T_s + T_r}$$

***Time for the operator to move between machines***

# Example

- A number of CNC Lathes produce similar products at a rate of 2.2 min. (cycle time = 2.2 min.)
- It takes an operator to load and unload the parts at 20 seconds ($T_s$ = 20) and it takes 15 sec. to get to each machine ($T_r$ = 15)
- There is no machine idle time.
- *How many machines can an operator handle?*

$$T_m = 2.2 \times 60 = 132 \; sec.$$

$$n = \frac{132 + 20}{20 + 15} = 4.34 \quad \textit{that is 4 machines per operator}$$

- $T_c = T_m + T_s \rightarrow T_c = 152$
- Operator service time = 4 X 20 = 80 sec, total walking time= 4X15= 60
- Workers idle time => 152 – 140 = 12 sec.

# Group Technology (GT) and Cellular Manufacturing (CM) (also see previous lecture notes)

***"GT is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage over their similarities and in design and production processes"*** **[Groover 2001]**

- The most common form of production in US
- Designed for batch manufacturing that needs to be more efficient and productive

# GT

- Parts are arranged in ***part families***
- The production/service equipment are arranged into groups or cells to facilitate work flow

**Benefits:**

- Standardisation of tooling, fixturing and setups
- Reduced material handling
- Process plans and schedules are improved
- Reduction in WIP
- Better quality work
- Higher specialised work-force and job satisfaction
- Improved part and tools **Tracking and Traceability**

# Production Flow Analysis (PFA) for GT and CM

- Pioneered by J. Burbridge (1963) is method for identifying part families and machine grouping based on production process flow (product route sheets)

- It uses manufacturing process data rather than design data overcoming:
  - **Parts that may have similar design attributes (geometries) but require different process routings**
  - **Parts that may have different design attributes (geometries) but require identical process routes**

# Simplistic Example PFA chart to determine Machine Grouping (Part Machine Incidence Matrix) [Groover 2001]

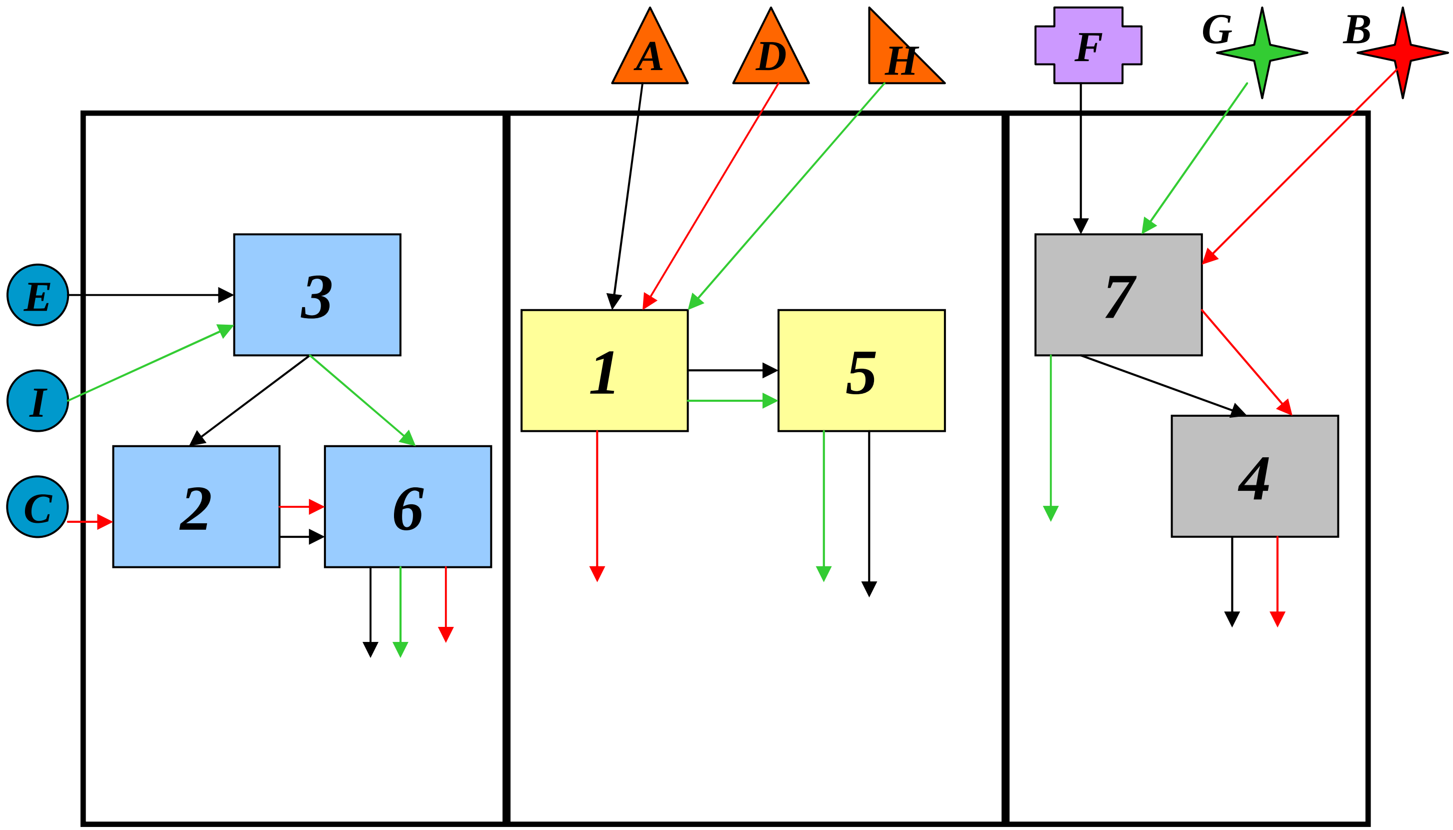
**Parts**

| Machines | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | | 1 | | | | 1 | |
| 2 | | | | | 1 | | | | 1 |
| 3 | | | 1 | | 1 | | | | 1 |
| 4 | | 1 | | | | 1 | | | |
| 5 | 1 | | | | | | | 1 | |
| 6 | | | 1 | | | | | | 1 |
| 7 | | 1 | | | | 1 | 1 | | |

**Parts**

| Machines | C | E | I | A | D | H | F | G | B |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 | | | | | | |
| 2 | | 1 | 1 | | | | | | |
| 6 | 1 | | 1 | | | | | | |
| 1 | | | | 1 | 1 | 1 | | | |
| 5 | | | | 1 | | 1 | | | |
| 7 | | | | | | | 1 | 1 | 1 |
| 4 | | | | | | | 1 | | 1 |

# Schematic Layout and Possible Part flow



# Quantitative Analysis in CM

1. Grouping parts and machines by **Rank Order Clustering**

2. Arranging machines in a GT cell
   - **Hollier Method 1**
   - **Hollier Method 2**

# 1. Grouping parts and machines by **Rank Order Clustering** [Groover 2001]

- Proposed by J. R. King (1980)
- Grouping machines into cells
- Works by reducing the part machine incidence matrix

# Part Machine incidence Matrix Algorithm

1. Read the series of 1 and 0s from left to right in the matrix as binary number $2^i$ *(0 to i - 1 number of rows)* . Rank the **rows** in order of decreasing values. In case of a tie, rank the rows in the same order as they appear in the current matrix.

2. Numbering from top to bottom, is the new order of rows the same as the rank order determined in the previous step? – If **YES** go to step 7. if **NO** got to next step.

3. Reorder the rows in the part-machine incidence matrix by listing them in decreasing rank order, start from the top.

# Part Machine incidence Matrix Algorithm cont.

4. In each **column** of the matrix, read the series of 1 and 0s from the top to the bottom of the binary number

$2^{j}$ *(0 to j - 1 number of columns)* rank the columns in order of decreasing value. In case of a tie, rank the columns in the same order as they appear in the current matrix.

5. Numbering from left to right, is the current order of columns the same as the rank order determined in the previous step? – if **YES** got to step 7, else go to next step
6. Reorder the columns in the part-machine incidence matrix by listing them in decreasing rank order, starting with the left column, go to step 1
7. Stop

# Example – First iteration

| | Parts | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Binary Values* | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ | | |
| **Machines** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **Decimal Value** | **Rank** |
| **1** | 1 | 1 | | 1 | | | | 1 | | 418 | 1 |
| **2** | | | | | 1 | | | | 1 | 17 | 7 |
| **3** | | | 1 | | 1 | | | | 1 | 81 | 5 |
| **4** | | 1 | | 1 | 1 | | | | | 168 | 3 |
| **5** | 1 | | | | | | | 1 | | 258 | 2 |
| **6** | | | 1 | | | | | | 1 | 65 | 6 |
| **7** | | 1 | | | | 1 | 1 | | | 140 | 4 |

# Example – Second iteration

| Machines | A | B | C | D | E | F | G | H | I | Binary Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Parts** | | | | | | | | | |
| 1 | 1 | 1 | | 1 | | | | 1 | | $2^6$ = 64 |
| 5 | 1 | | | | | | | 1 | | 32 |
| 4 | | 1 | | 1 | | 1 | | | | 16 |
| 7 | | 1 | | | | 1 | 1 | | | 8 |
| 3 | | | 1 | | 1 | | | | 1 | 4 |
| 6 | | | 1 | | | | | | 1 | 2 |
| 2 | | | | | 1 | | | | 1 | $2^0$ = 1 |
| Decimal Value | 96 | 88 | 6 | 80 | 5 | 24 | 8 | 96 | 7 | |
| Rank | 1 | 3 | 8 | 4 | 9 | 5 | 6 | 2 | 7 | |

# Example – Solution [Groover 2001 – more examples]

**Parts**

| **Machines** | **A** | **H** | **B** | **D** | **F** | **G** | **I** | **C** | **E** |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | 1 | 1* | 1* | | | | | |
| **5** | 1 | 1 | | | | | | | |
| **4** | | | 1 | 1 | 1 | | | | |
| **7** | | | 1 | | 1 | 1 | | | |
| **3** | | | | | | | 1 | 1 | 1 |
| **6** | | | | | | | 1 | 1 | |
| **2** | | | | | | | 1 | | 1 |

* Parts B & D can be put in either of the two machine groups since they require machines from groups **(overlapping)**

# Another alternative to overlapping – adding another Machine 1

| Machines | Parts: A | H | B | D | F | G | I | C | E |
|---|---|---|---|---|---|---|---|---|---|
| 1a | 1 | 1 | | | | | | | |
| 5 | 1 | 1 | | | | | | | |
| 4 | | | 1 | 1 | 1 | | | | |
| 1b | | | 1 | 1 | | | | | |
| 7 | | | 1 | | 1 | 1 | | | |
| 3 | | | | | | | 1 | 1 | 1 |
| 6 | | | | | | | 1 | 1 | |
| 2 | | | | | | | 1 | | 1 |

# 2. Arranging machines in a GT cell

- After grouping machines into corresponding cells one needs to arrange them within the cell to minimise material handling between machines.

- Hollier Methods

# Hollier Method 1

1. Develop a **From-To** chart from process plan data

2. Determine sum of trips **From** and **To** the machines

3. Assign machines to the cell based on minimum **From** or **To** sums
   - **(**if the lowest is a To (column), then it goes to the beginning – if the lowest is From (row), then the machine goes to the end.
   - If a tie occurs on a row or a column, then the machine with minimum From/To ratio is selected
   - If both are the same it is passed over and the next machine with the lowest value is selected to go to the beginning or the end of the sequence

4. Once a machine is selected reformat the **From-To** chart

# Example [Groover 2001]

- Suppose there are 4 machines (1, 2, 3, and 4) in a cell
- 50 parts are to be processed shown in table (1-1)
- 50 parts enter the group at machine 3, 20 parts leave after being processed at machine 1, and 30 parts leave after machine 4
- Find a logical arrangement for the machines in the cell …

**Table 1-1: From-To chart**

| | **To** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| **From** | **1** | 0 | 5 | 0 | 25 |
| | **2** | 30 | 0 | 0 | 15 |
| | **3** | 10 | 40 | 0 | 0 |
| | **4** | 10 | 0 | 0 | 0 |

# Example cont.

Solution [3→ 2 → → ]

Table 1-2 From-To chart

| | To | 1 | 2 | 3 | 4 | From Sums |
|---|---|---|---|---|---|---|
| **From** | **1** | 0 | 5 | 0 | 25 | **30** |
| | **2** | 30 | 0 | 0 | 15 | **45** |
| | **3** | 10 | 40 | 0 | 0 | **50** |
| | **4** | 10 | 0 | 0 | 0 | **10** |
| **To Sums** | | **50** | **45** | **0** | **40** | |

Table 1-3 From-To chart

| | To | 1 | 2 | 4 | From Sums |
|---|---|---|---|---|---|
| **From** | **1** | 0 | 5 | 25 | **30** |
| | **2** | 30 | 0 | 15 | **45** |
| | **4** | 10 | 0 | 0 | **10** |
| **To Sums** | | **50** | **5** | **40** | |

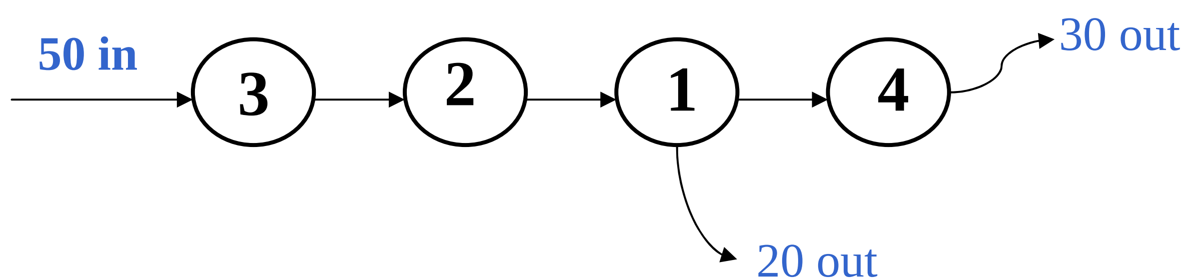
# Example cont.

**Solution: [3 → 2 → 1 → 4 ]**

**Table 1-4 From-To chart**

| | To | 1 | 4 | From Sums |
|---|---|---|---|---|
| **From** | **1** | 0 | 25 | **25** |
| | **4** | 10 | 0 | **10** |
| **To Sums** | | **10** | **25** | |

***Lowest is in the row***



# Hollier Method 2

1. Develop the **From-To** chart
2. Determine the **From-To ratio for each machine**

   *Sum Row / Sum of corresponding column*

3. *Arrange machines in the order of decreasing From-To ratio*

# Example 2

**Table From-To chart**

| | To | 1 | 2 | 3 | 4 | From Sums | From-To ratio |
|---|---|---|---|---|---|---|---|
| **From** | **1** | 0 | 5 | 0 | 25 | 30 | 30/50 = 0.6 |
| | **2** | 30 | 0 | 0 | 15 | 45 | 45/45 = 1 |
| | **3** | 10 | 40 | 0 | 0 | 50 | 50/0 = ∞ |
| | **4** | 10 | 0 | 0 | 0 | **10** | 10/40 = 0.25 |
| **To Sums** | | **50** | **45** | **0** | **40** | | |

***Solution = [3 → 2 → 1 → 4 ]***