Problem 10
Common Grouping

E212 – Facilities Planning and Design

SCHOOL OF ENGINEERING

E212 Facilities Planning & Design - Topic Tree

- Facilities Planning and Design
  - Introduction (P01)
  - Facilities Location (P02)
    - AHP
    - FAT
  - Facilities Design
    - Production Floor
      - Types of Layouts (P03)
      - Graph-Based Layouts (P04)
      - Flow Analysis (P05)
      - Space Considerations (P06)
      - Clustering Technique (P10)
    - Storage Facilities
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      - Material Handling (P09)
    - Office (P11)
    - Carpark (P12)
      - Docking
      - Parking
  - Welfare Safety and Security (P10)
  - Final Layout (P13)
    - CORELAP

Learning Objectives

- Describe Group Layout, Group Technology, Cellular Manufacturing, and their associated advantages and limitations.

- Identify machine cells and part families simultaneously, and to allocate part families to machine cells in order to minimize intercellular movement of parts through:

  - Row & Column Masking (R&CM) Algorithm

  - Rank Order Clustering Algorithm

- Compare and contrast the similarity and differences between using Row & Column Masking Algorithm vs Rank Order Clustering Algorithm.

- Perform an appropriate cell manufacturing (or work cell) design.

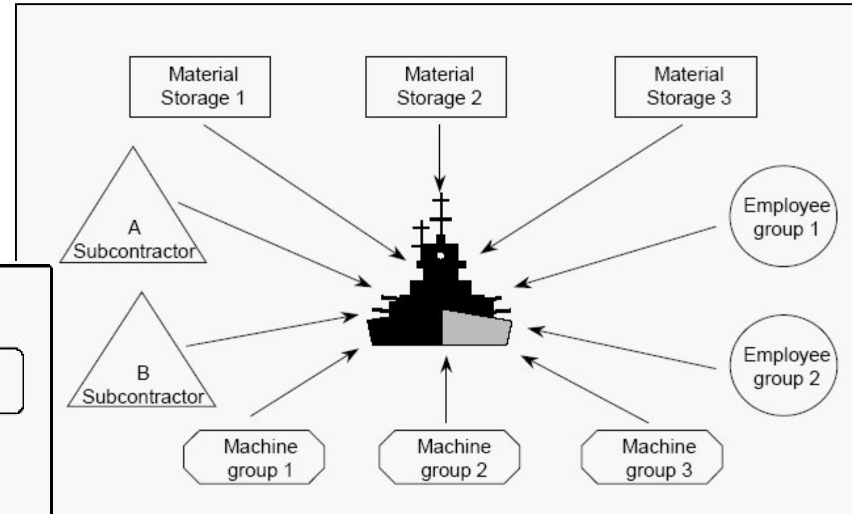
- Draft out a facility layout using AutoCAD.

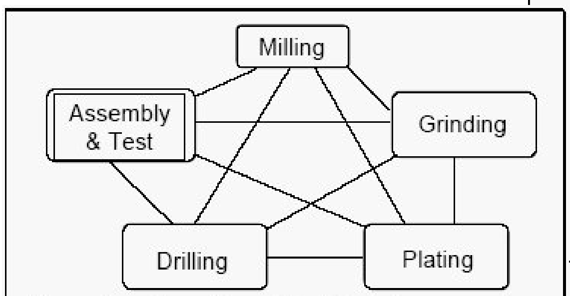
Recap: Basic Layout Types

(Problem #03)

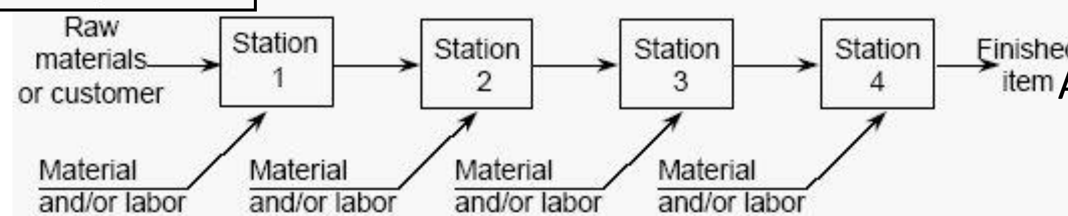
<u>Basic layout types</u>:

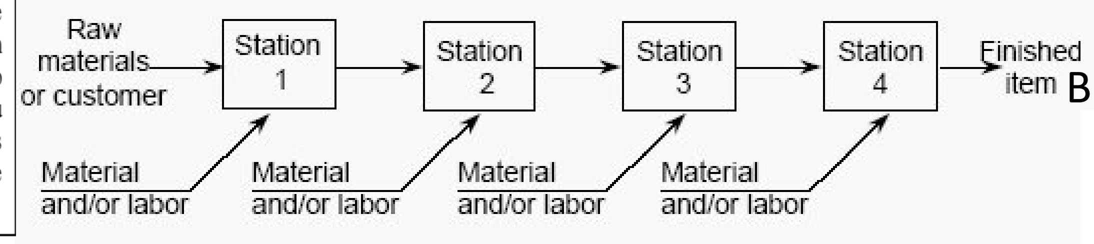
1. Fixed-position
2. Product
3. Process
4. Cellular
5. Mixed

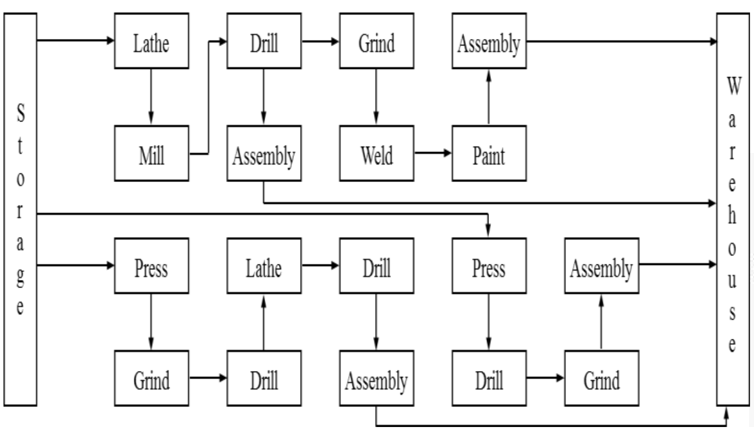




Process Layout - work travels to dedicated process centers







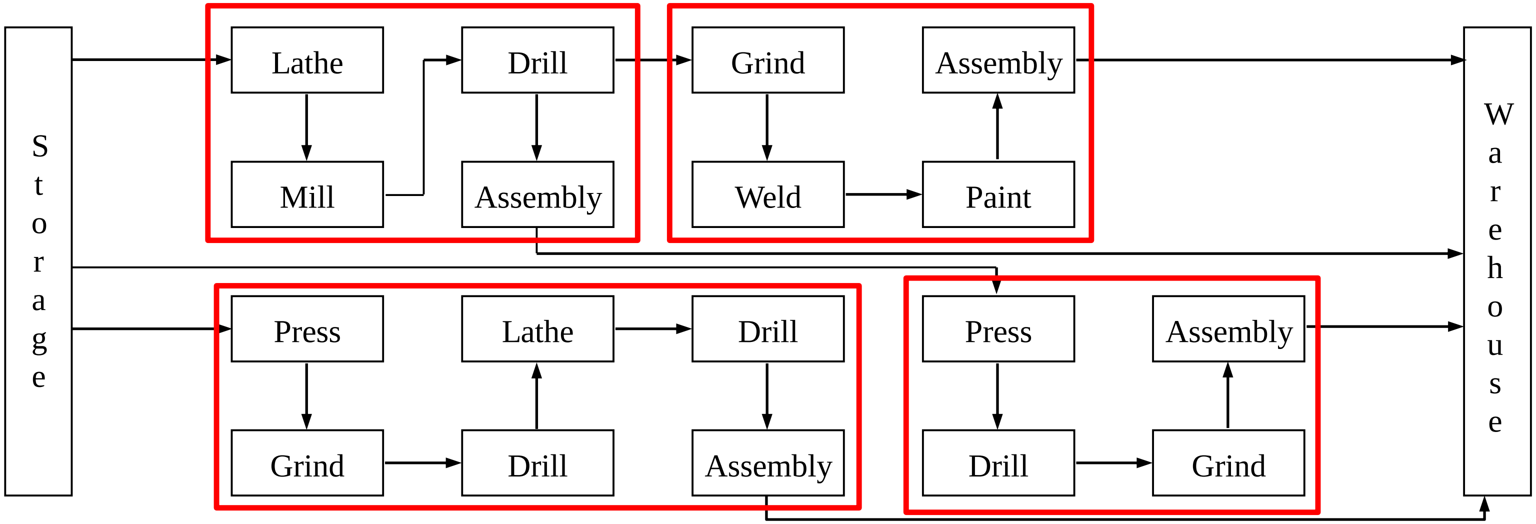
Group Layout

Group Layout (also known as cellular layout or group technology layout) is a type of layout in which machines are grouped into a cell that can handle items with similar processing requirements. It is often regarded as an equipment/machine layout configured to support Cellular Manufacturing (CM).

In Group Layout:

- Products/parts are being grouped into "product or part families" based on their similarities such as common processing sequences, material composition, tooling requirements, handling requirements, storage requirements, control requirements, etc.
- The processing equipment or machines required are then grouped and arranged into a manufacturing cell or work cell, based on the corresponding product or part family that they handle.

Group Layout



When the production volumes for the individual products are not sufficient to justify for pure product layouts, Group Layout is a better alternative as the equipment/machines can be better utilized for manufacturing the several type of products belonging to the same product family.

Group Layout

Some **advantages** of Group Layout include:

1. More products (with similarities) can be produced by the same machines
2. Supports the use of general purpose machines/equipment.
3. Compromise between product layout and process layout – with associated advantages.
4. Shorter travel distances and smoother flow lines than for process layout.
5. Team attitude and job enlargement tend to occur.

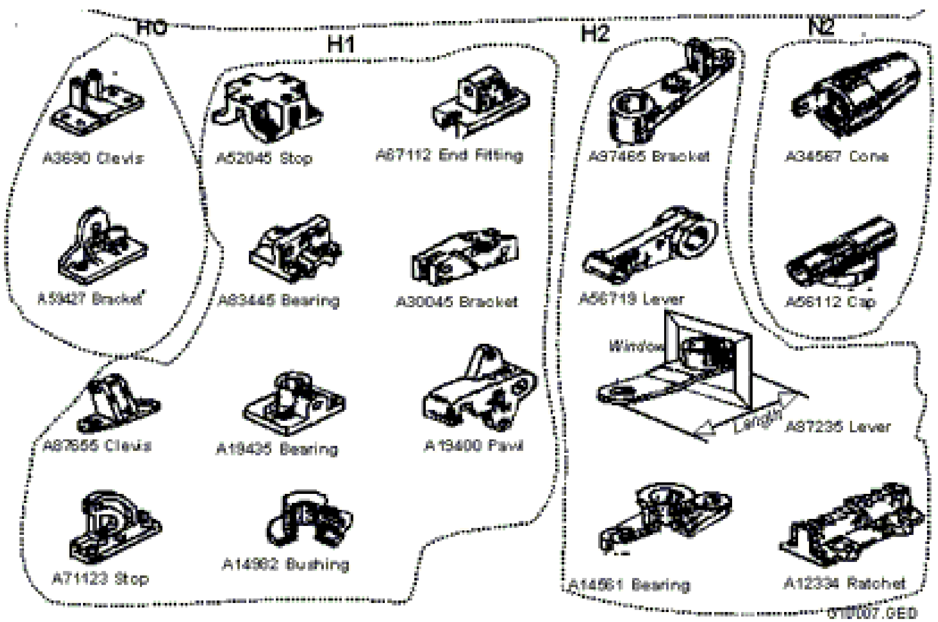
Some **limitations** of Group Layout include:

1. Higher skill levels is required of employees (compared to product layout).
2. General supervision is required.
3. Compromise between product layout and process layout – with associated limitations.
4. Depends on balanced material flow through the cell. Otherwise, buffers and work-in-process inventories will be built up.

Group Technology (GT)

Group Technology (GT) - a management philosophy that attempts to <u>group products / parts</u> with similar design or manufacturing characteristics, or both.

By grouping similar parts together, a common set of strategy can be developed to handle their required processing, thus saving time and effort.



A group of similar parts is known as a "part family".

Cellular Manufacturing (CM)

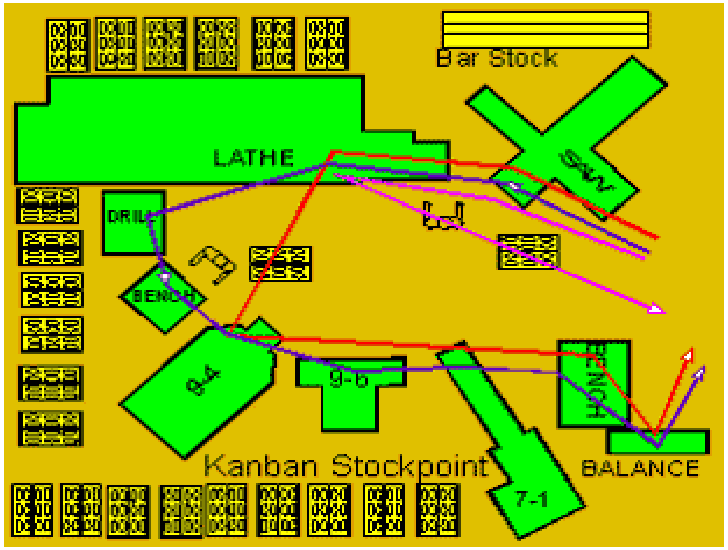
Cellular Manufacturing (CM) - an application of GT that involves grouping equipment / machines based on the parts manufactured by them.

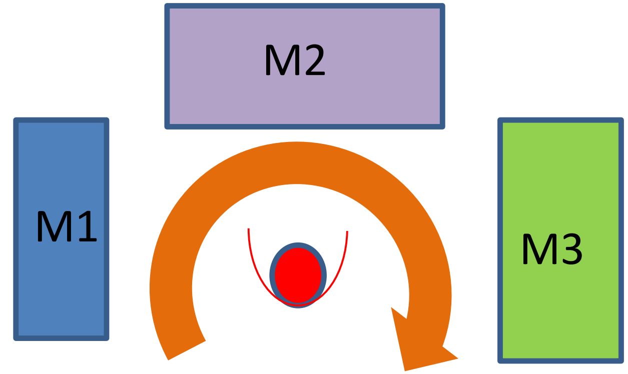
A group of machineries arranged to process a particular part family is known as a machine cell, or work cell.

This type of manufacturing in which a part family is produced by a machine cell is known as cellular manufacturing.

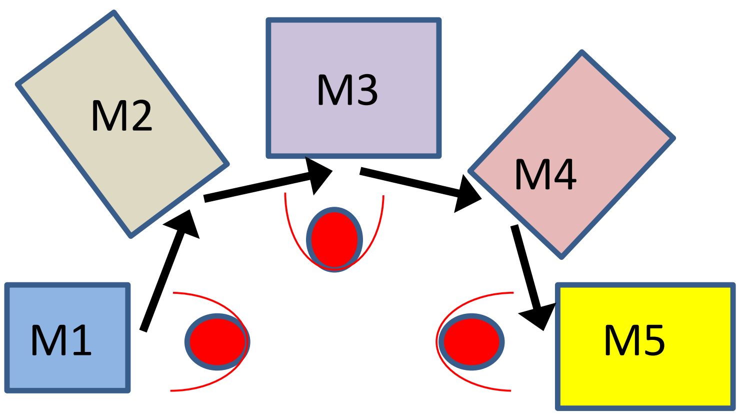
A Typical U-shaped Work Cell

Cellular Manufacturing (Examples)

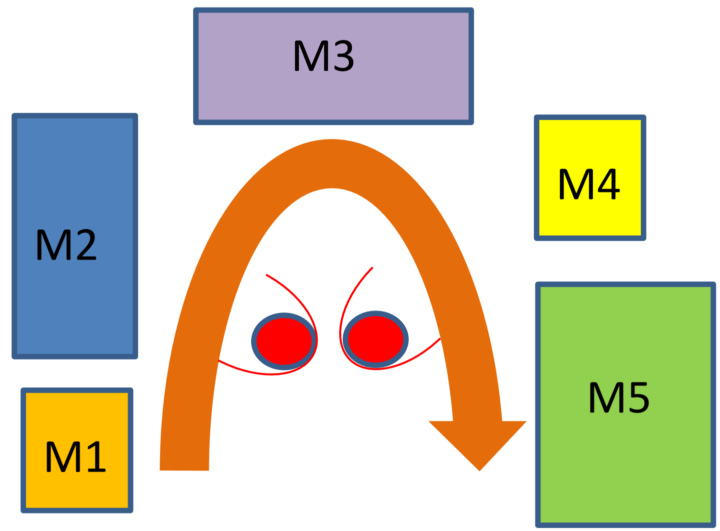




A "1 Man – 3 Machines" Work Cell

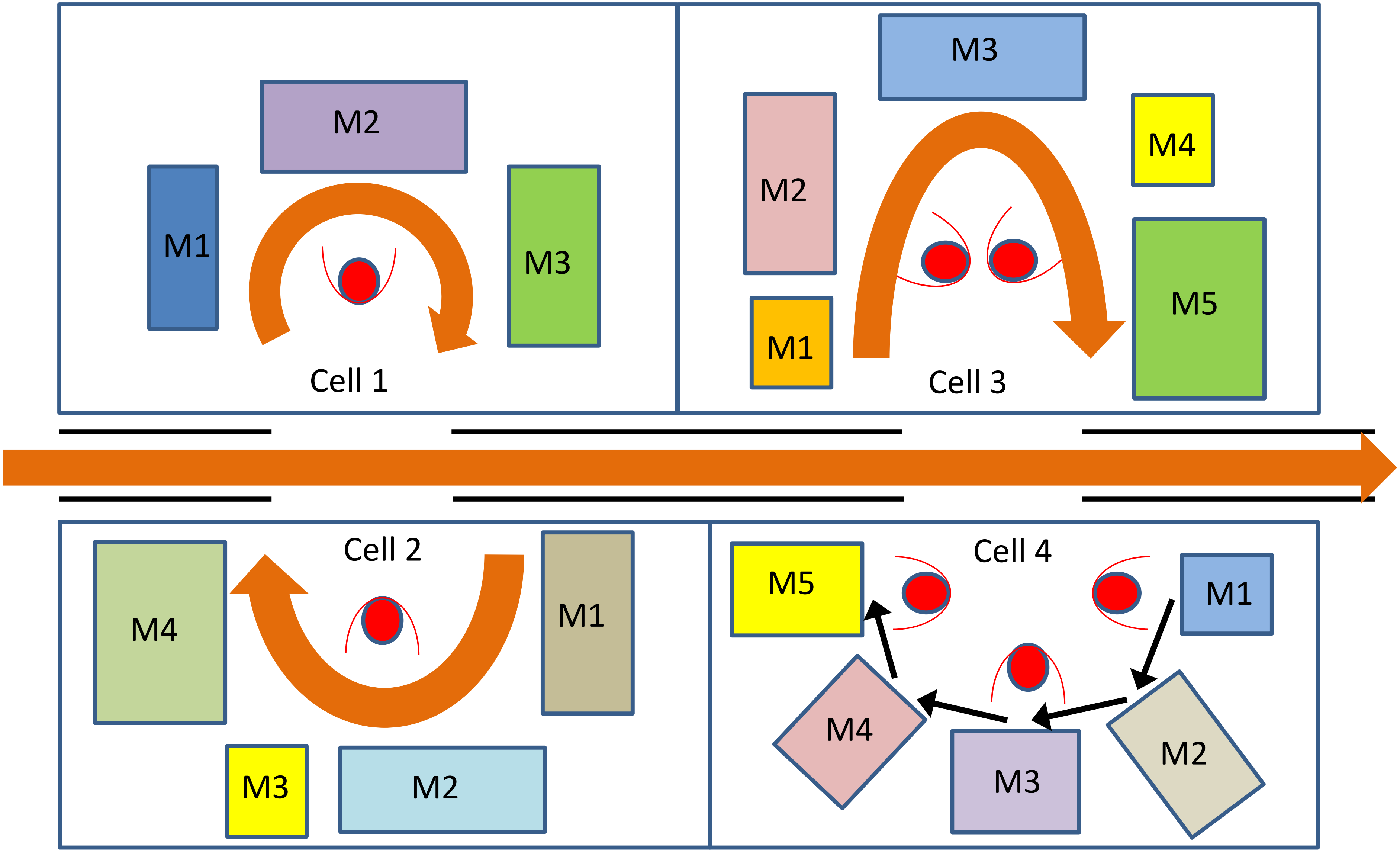


A 3 Man – 5 Machines Work Cell



A "2 Man – 5 Machines Work Cell

Cellular Manufacturing (Examples)



Potential Benefits of Group Technology & Cellular Manufacturing

Increases:

- Productivity. (compared to process layout)
- Components standardization.
- Reliability of estimates/forecasts.
- Costing accuracy.
- Material flow.
- Machine utilization.
- Space utilization.
- Quality.
- Customer service.
- Order potential.
- Employee morale.
- Etc…

Reduces:

- Planning effort.
- Paper work
- Setup time.
- Down-time.
- Work-in-process (WIP) inventory.
- Work movement.
- Overall production time.
- Material handling cost.
- Direct/indirect labour cost.
- Overall costs.
- Etc…

Group Technology: Clustering Techniques

Clustering Techniques - a class of methods concerned with identifying machine cells, corresponding part families, or both by attempting to rearrange the row and columns of the machine-part indicator matrix until a block diagonal form can be identified.

Some of the commonly used clustering algorithms include:

1. Row & Column Masking (R&CM)
2. Rank Order Clustering (ROC)

E-learning video for Row & Column Masking (R&CM) :
https://drive.google.com/file/d/0B3HLYdhAzz2eQlpaSGg4VmRMUzg/edit?usp=sharing

E-learning video for Rank Order Clustering (ROC) :
https://drive.google.com/file/d/0B3HLYdhAzz2eZl92ZC1SOUw5ZHc/edit?usp=sharing

Row & Column Masking Algorithm

The steps in using the Row & Column Masking Algorithm are as follows:

1. Draw a horizontal line across the 1st row. Select any ‘1’ entry in the matrix which is cut through only by one line.

2. If the entry is cut through by a horizontal line, go to step 2a. If the entry is cut through by a vertical line, go to step 2b.

2a. Draw a vertical line down the column in which this ‘1’ entry appears.
Go to step 3.

2b. Draw a horizontal line across the row in which this ‘1’ entry appears.
Go to step 3.

3. Look for any ‘1’ entry with only one line cutting through it, select any one and go to step 2. Repeat until there are no more such entries left. Identify the corresponding machine cell and part family. Go to step 4.

4. Select any row through which there is no line yet. If there are no such rows, stop. Otherwise, draw a horizontal line across this row, and select any ‘1’ entry in the matrix which is cut through by only one line. Go to step 2.

Rank Order Clustering Algorithm

The steps in using the Rank Order Clustering Algorithm are as follows:

1. Assign **binary weights $BW_i = 2^{m-i}$** to each **row *i*** of the machine-part indicator matrix, where m is the number of machines.
2. Determine the **decimal equivalent (DE)** of the binary value of each **column *j*** using the formula:
$$DE_j = \sum_{i=1}^{m} (BW_i)(a_{ij})$$
3. Rank the columns in decreasing order of their DE values. Break ties arbitrarily.. Rearrange the columns based on this ranking. If no rearrangement is necessary, stop. Otherwise, go to step 4.
4. For each rearranged **column *j*** of the matrix, assign **binary weights $BW_j = 2^{n-j}$,** where n is the number of parts
5. Determine the **decimal equivalent (DE)** of the binary value of each **row *i*** using the formula:
$$DE_i = \sum_{j=1}^{n} (BW_j)(a_{ij})$$
6. Rank the rows in decreasing order of their DE values. Break ties arbitrarily. Rearrange the rows based on this ranking. If no rearrangement is necessary, stop. Otherwise, go to step 1.

Problem 10
Suggested Solution

Row & Column Masking Algorithm

Assign the codes to represent all the Parts and Machines for easy reference:

Component Parts	Raw Materials	Machines
P1: Metal Front Casing	2mm Aluminium Rod	M1: Drilling Machine
P2: Plastic Back Casing	PP Plastic Pellets	M2: Motor & Electronics Station
P3: Fan Blades	0.5 Aluminium Sheet	M3: Winding Machine
P4: Electrical	Non metal Cable	M4: Painting Machine
P5: Motor	Motor Plates	M5: Cutting & Welding Machine
		M6: Plastic Molding Machine
		M7: Pressing Machine
		M8: Bending Machine

Row & Column Masking Algorithm

(Components Parts)

(Types of Machines/Equipment)

	P1	P2	P3	P4	P5
M1	1	1	0	0	1
M2	0	0	0	0	1
M3	0	0	0	1	0
M4	1	1	0	0	0
M5	1	0	1	0	0
M6	0	1	0	0	0
M7	0	0	0	1	0
M8	1	0	1	0	0

To begin:

Arrange the machines and products into a matrix as shown on the left.

Enter a ‘**1**’ for a product (P) that is processed by a machine (M).

Enter a ‘**0**’ for a product (P) that is not processed by a machine (M).

Row & Column Masking Algorithm

		P1	P2	P3	P4	P5
1	**M1**	1	1	0	0	1
	M2	0	0	0	0	1
	M3	0	0	0	1	0
	M4	1	1	0	0	0
	M5	1	0	1	0	0
	M6	0	1	0	0	0
	M7	0	0	0	1	0
	M8	1	0	1	0	0

Step I:

Draw a single horizontal line (#1) across the 1st row.

Row & Column Masking Algorithm

2 3 4

1

	P1	P2	P3	P4	P5
M1	1	1	0	0	1
M2	0	0	0	0	1
M3	0	0	0	1	0
M4	1	1	0	0	0
M5	1	0	1	0	0
M6	0	1	0	0	0
M7	0	0	0	1	0
M8	1	0	1	0	0

Step II:

Identify the 'I' entry in the matrix which is cut through only by one single line. As these two 'I' entry is cut through by a horizontal line, draw single vertical lines down the columns in which this 'I' entries appears.

Row & Column Masking Algorithm

	P1	P2	P3	P4	P5
M1	$\boxed{1}$	$\boxed{1}$	0	0	$\boxed{1}$
M2	0	0	0	0	$\boxed{1}$
M3	0	0	0	1	0
M4	$\boxed{1}$	$\boxed{1}$	0	0	0
M5	$\boxed{1}$	0	1	0	0
M6	0	$\boxed{1}$	0	0	0
M7	0	0	0	1	0
M8	$\boxed{1}$	0	1	0	0

Step III:

Identify all the ‘I’ entries in the matrix which is cut through only by one single line. As these ‘I’ entries are cut through by vertical lines, draw a single horizontal line across the rows in which these ‘I’ entries appears.

Row & Column Masking Algorithm

		2	3	10		4
		P1	P2	P3	P4	P5
1	M1	1	1	0	0	1
5	M2	0	0	0	0	1
	M3	0	0	0	1	0
6	M4	1	1	0	0	0
7	M5	1	0	1	0	0
8	M6	0	1	0	0	0
	M7	0	0	0	1	0
9	M8	1	0	1	0	0

Step IV: Identify all the 'I' entries in the matrix which is cut through only by one single line.(Row 10) After it is observed that there are no more 'I' entries with only a one line cutting through it (i.e. all 'I' are now crossed), we can hence determine the first group of machine cell and part family:

Group 1:

P1, P2, P3

M1, M2, M4, M5, M6, M8

Row & Column Masking Algorithm

		2	3	10		4
		P1	**P2**	**P3**	**P4**	**P5**
1	**M1**	1	1	0	0	1
5	**M2**	0	0	0	0	1
1	**M3**	0	0	0	$\boxed{1}$	0
6	**M4**	1	1	0	0	0
7	**M5**	1	0	1	0	0
8	**M6**	0	1	0	0	0
	M7	0	0	0	1	0
9	**M8**	1	0	1	0	0

Step V:

Select any row through which there is no line yet, and draw a double horizontal line across that row.

Row & Column Masking Algorithm

		2	3	10	2	4
		P1	**P2**	**P3**	**P4**	**P5**
1	**M1**	1	1	0	0	1
5	**M2**	0	0	0	0	1
1	**M3**	0	0	0	1	0
6	**M4**	1	1	0	0	0
7	**M5**	1	0	1	0	0
8	**M6**	0	1	0	0	0
2	**M7**	0	0	0	1	0
9	**M8**	1	0	1	0	0

Step VI:

Identify all the ‘I’ entries in the matrix which is cut through only by one double line. As these ‘I’ entries are cut through by a horizontal line, draw a double vertical line down each of the columns in which these ‘I’ entries appears.

Row & Column Masking Algorithm

		2	3	10	2	4
		P1	**P2**	**P3**	**P4**	**P5**
1	**M1**	1	1	0	0	1
5	**M2**	0	0	0	0	1
1	**M3**	0	0	0	1	0
6	**M4**	1	1	0	0	0
7	**M5**	1	0	1	0	0
8	**M6**	0	1	0	0	0
2	**M7**	0	0	0	1	0
9	**M8**	1	0	1	0	0

Step VII:

Now that it is observed that there are no more 'I' entries with only a one double line cutting through it, we can hence determine the second group of machine cell and part family:

Group 2:

P4

M3, M7

Row & Column Masking Algorithm

The following grouping, as derived from the Row & Column Masking Algorithm, shall be presented to the Goodle Corporation for consideration:

Component Parts	Machines
P1: Metal Front Casing	M1: Drilling Machine
P2: Plastic Back Casing	M2: Motor & Electronics Station
P3: Fan Blades	M3: Winding Machine
P4: Electrical	M4: Painting Machine
P5: Motor	M5: Cutting & Welding Machine
	M6: Plastic Molding Machine
	M7: Pressing Machine
	M8: Bending Machine

Group 1: (P1, P2, P3, P5), (M1, M2, M4, M5, M6, M8)
Group 2: (P4), (M3, M7)

Possible Limitation of R&CM

- If the machine-part matrix contains one or more machines that belong to more than one cell, or contains parts that are processed in more than one cell, using R&CM may provide a solution with all machines in a cell and all parts in a corresponding part family – unable to differentiate!

Possible Limitation of R&CM

- For parts that cannot be completed in one cell alone:
  - – Modify manufacturing process of parts (may involve modifications to parts design)
  - – Use ROC to do the parts and machine grouping, and:
    - Design effective inter-cellular material handling system.
    - Duplicate machines.

Rank Order Clustering (ROC) Algorithm

Similar to R&CM, let's assign the codes below to represent all the Parts and Machines:

Component Parts	Raw Materials	Machines
P1: Metal Front Casing	2mm Aluminium Rod	M1: Drilling Machine
P2: Plastic Back Casing	PP Plastic Pellets	M2: Motor & Electronics Station
P3: Fan Blades	0.5 Aluminium Sheet	M3: Winding Machine
P4: Electrical	Non-metal Cable	M4: Painting Machine
P5: Motor	Motor Plates	M5: Cutting & Welding Machine
		M6: Plastic Molding Machine
		M7: Pressing Machine
		M8: Bending Machine

Rank Order Clustering(ROC) Algorithm

(Components Parts)

(Types of Machines/Equipment)

	P1	P2	P3	P4	P5
M1	1	1	0	0	1
M2	0	0	0	0	1
M3	0	0	0	1	0
M4	1	1	0	0	0
M5	1	0	1	0	0
M6	0	1	0	0	0
M7	0	0	0	1	0
M8	1	0	1	0	0

To begin:

Arrange the machines and products into a matrix as shown on the left.

Enter a '**1**' for a product (P) that is processed by a machine (M).

Enter a '**0**' for a product (P) that is not processed by a machine (M).

Rank Order Clustering(ROC) Algorithm

	P1	P2	P3	P4	P5	
M1	1	1	0	0	1	2^7
M2	0	0	0	0	1	2^6
M3	0	0	0	1	0	2^5
M4	1	1	0	0	0	2^4
M5	1	0	1	0	0	2^3
M6	0	1	0	0	0	2^2
M7	0	0	0	1	0	2^1
M8	1	0	1	0	0	2^0

Assign Binary Weights to each row *i*

Step I:

Assign Binary Weight $\mathbf{BW_i = 2^{m-i}}$ to each **row** ***i*** of the matrix, where ***m*=8** (the number of machines).

Rank Order Clustering(ROC) Algorithm

	P1	P2	P3	P4	P5	
M1	1	1	0	0	1	128
M2	0	0	0	0	1	64
M3	0	0	0	1	0	32
M4	1	1	0	0	0	16
M5	1	0	1	0	0	8
M6	0	1	0	0	0	4
M7	0	0	0	1	0	2
M8	1	0	1	0	0	1
DE of the binary values of each column *j*	153	148	9	34	192	

Step II:

Calculate the **Decimal Equivalent (DE)** of the binary values of each **column *j*** using the formula:

$$DE_j = \sum_{i=1}^{m} (BW_i)(a_{ij})$$

e.g. DE_5= (128x1) + (64x1) (32x0)+ (16x0) + (8x0) + (4x0)+ (2x0) + (1x0)
= 128 + 64 + 0 + 0 + 0 + 0 + 0 + 0 = 192

Rank Order Clustering(ROC) Algorithm

	P1	P2	P3	P4	P5	
M1	1	1	0	0	1	128
M2	0	0	0	0	1	64
M3	0	0	0	1	0	32
M4	1	1	0	0	0	16
M5	1	0	1	0	0	8
M6	0	1	0	0	0	4
M7	0	0	0	1	0	2
M8	1	0	1	0	0	1
	153	148	9	34	192	
Rank of DE values →	2	3	5	4	1	

Step III:

Rank the columns in decreasing order of their DE values.

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3
M1	1	1	1	0	0
M2	1	0	0	0	0
M3	0	0	0	1	0
M4	0	1	1	0	0
M5	0	1	0	0	1
M6	0	0	1	0	0
M7	0	0	0	1	0
M8	0	1	0	0	1
	$\boxed{192}$	$\boxed{153}$	$\boxed{148}$	$\boxed{34}$	$\boxed{9}$
	1	2	3	4	5

Step IV:
Re-arrange the columns in the running order of the rankings.

Columns re-arranged in order of Rankings

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3
M1	1	1	1	0	0
M2	1	0	0	0	0
M3	0	0	0	1	0
M4	0	1	1	0	0
M5	0	1	0	0	1
M6	0	0	1	0	0
M7	0	0	0	1	0
M8	0	1	0	0	1
	$\boxed{2^4}$	$\boxed{2^3}$	$\boxed{2^2}$	$\boxed{2^1}$	$\boxed{2^0}$

Assign
Binary Weights
to each column *j*

Step V:

Assign binary weight $\mathbf{BW_j = 2^{n-j}}$ to each **column *j*** of the matrix, where ***n*=6** (the number of parts).

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3	
M1	1	1	1	0	0	28
M2	1	0	0	0	0	16
M3	0	0	0	1	0	2
M4	0	1	1	0	0	12
M5	0	1	0	0	1	9
M6	0	0	1	0	0	4
M7	0	0	0	1	0	2
M8	0	1	0	0	1	9
	16	8	4	2	1	

DE of the binary values of each row *i*

Step VI:

Calculate the **Decimal Equivalent (DE)** of the binary values of each **row *i*** using the formula:

$$DE_i = \sum_{j=1}^{n} (BW_j)(a_{ij})$$

e.g. DE_6= (16x0) + (8x1) + (4x0) + (2x0) + (1x1) = 0+8+0+0+0+1 = 9

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3		
M1	1	1	1	0	0	28	1
M2	1	0	0	0	0	16	2
M3	0	0	0	1	0	2	7
M4	0	1	1	0	0	12	3
M5	0	1	0	0	1	9	4
M6	0	0	1	0	0	4	6
M7	0	0	0	1	0	2	8
M8	0	1	0	0	1	9	5
	16	8	4	2	1		

Rank of DE values

Step VII:
Rank the rows in decreasing order of their DE values.

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3		
M1	1	1	1	0	0	28	1
M2	1	0	0	0	0	16	2
M4	0	1	1	0	0	12	3
M5	0	1	0	0	1	9	4
M8	0	1	0	0	1	9	5
M6	0	0	1	0	0	3	6
M3	0	0	0	1	0	2	7
M7	0	0	0	1	0	2	8
	16	8	4	2	1		

Rows re-arranged
in order of Rankings

Step VIII:
Re-arrange the rows in the running order of the rankings.

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3
M1	1	1	1	0	0
M2	1	0	0	0	0
M4	0	1	1	0	0
M5	0	1	0	0	1
M8	0	1	0	0	1
M6	0	0	1	0	0
M3	0	0	0	1	0
M7	0	0	0	1	0

$\boxed{2^7}$
$\boxed{2^6}$
$\boxed{2^5}$
$\boxed{2^4}$
$\boxed{2^3}$
$\boxed{2^2}$
$\boxed{2^1}$
$\boxed{2^0}$

Assign Binary Weights to each row *i*

Step IX:

Assign binary weight $\mathbf{BW_i = 2^{m-i}}$ to each **row** ***i*** of the matrix, where ***m*=7** (the number of machines).

(Note that this is like a repeat of step 1 again)

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P4	P3	
M1	1	1	1	0	0	2^7
M2	1	0	0	0	0	2^6
M4	0	1	1	0	0	2^5
M5	0	1	0	0	1	2^4
M8	0	1	0	0	1	2^3
M6	0	0	1	0	0	2^2
M3	0	0	0	1	0	2^1
M7	0	0	0	1	0	2^0
	192	184	164	2	24	

Step XI:

Calculate the **decimal equivalent (DE)** of the binary values of each **column *j*** using the formula:

$$DE_j = \sum_{i=1}^{m} (BW_i)(a_{ij})$$

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P3	P4	
M1	1	1	1	0	0	2^7
M2	1	0	0	0	0	2^6
M4	0	1	1	0	0	2^5
M5	0	1	0	1	0	2^4
M8	0	1	0	1	0	2^3
M6	0	0	1	0	0	2^2
M3	0	0	0	0	1	2^1
M7	0	0	0	0	1	2^0
	192	184	164	24	2	
Rank of DE values →	1	2	3	5	4	

Step X:

Rank the columns in decreasing order of their DE values.

Rank Order Clustering(ROC) Algorithm

	P5	P1	P2	P3	P4	
M1	1	1	1	0	0	2^7
M2	1	0	0	0	0	2^6
M4	0	1	1	0	0	2^5
M5	0	1	0	1	0	2^4
M8	0	1	0	1	0	2^3
M6	0	0	1	0	0	2^2
M3	0	0	0	0	1	2^1
M7	0	0	0	0	1	2^0
	192	184	164	24	2	

Step XII:

Since the ranking is now already neatly arranged in order, stop the process. We can now identify the groupings.

Group 1: (P1, P2, P3, P5), (M1, M2, M4, M5, M6, M8)

Group 2: (P4),(M3, M7)

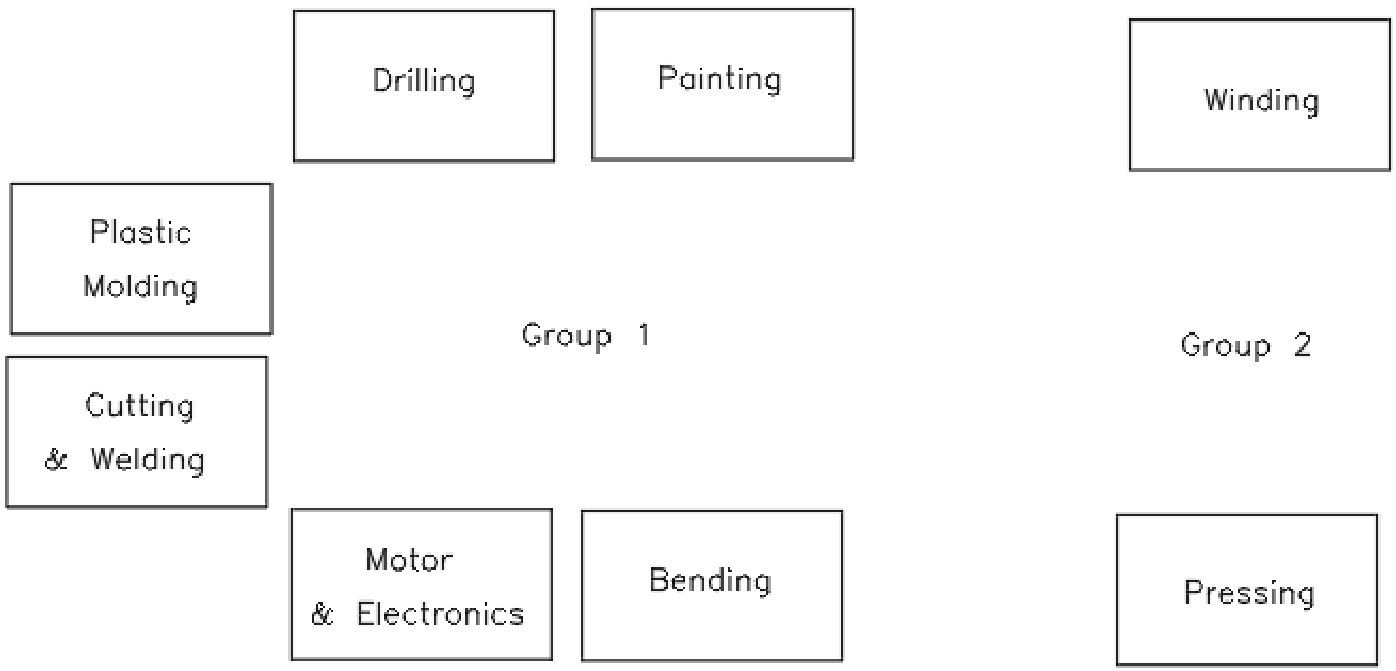
Rank Order Clustering(ROC) Algorithm

The following grouping, as derived from the Rank Order Clustering Algorithm, shall be presented to the Goodle Corporation for consideration:

Component Parts	Machines
P1: Metal Front Casing	M1: Drilling Machine
P2: Plastic Back Casing	M2: Motor & Electronics Station
P3: Fan Blades	M3: Winding Machine
P4: Electrical	M4: Painting Machine
P5: Motor	M5: Cutting & Welding Machine
	M6: Plastic Molding Machine
	M7: Pressing Machine
	M8: Bending Machine

Group 1: (P1, P2, P3, P5), (M1, M2, M4, M5, M6, M8)
Group 2: (P4), (M3, M7)

Suggested Machine Arrangement



Group 1: (P1, P2, P3, P5) **Group 2:** (P4)

Learning Objectives

- Describe Group Layout, Group Technology, Cellular Manufacturing, and their associated advantages and limitations.
- Identify machine cells and part families simultaneously, and to allocate part families to machine cells in order to minimize intercellular movement of parts through:
  - Row & Column Masking (R&CM) Algorithm
  - Rank Order Clustering Algorithm
- Compare and contrast the similarity and differences between using Row & Column Masking Algorithm vs Rank Order Clustering Algorithm.
- Perform an appropriate cell manufacturing (or work cell) design.
- Draft out a facility layout using AutoCAD.

Overview of E212 Facilities Planning and Design