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AUTOMATION IN PRODUCTION SYSTEMS AND MANAGEMENT

Cellular Manufacturing System

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Cellular Manufacturing System

- **Lecture-1:** Concept and Definition of Cellular Manufacturing System (CMS)
- **Lecture-2:** Cell Formation Approaches-I
- **Lecture-3:** Cell Formation Approaches-II
- **Lecture-4:** Evaluation of Cell Design, Numerical Examples
- **Lecture-5:** Production Planning and Control in CMS

Cellular Manufacturing System

- ✓ **Concept and Definition of Cellular Manufacturing System (CMS)**

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What is Cellular Manufacturing

- Cellular manufacturing is an application of group technology in manufacturing in which all or a portion of a firm's manufacturing system has been converted into cells.
- A manufacturing cell is a cluster of machines or processes located in close proximity and dedicated to the manufacture of a family of parts.
- The parts are similar in their processing requirements, such as operations, tolerances, and machine tool capacities.

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What is Cellular Manufacturing

- The primary objectives in implementing a cellular manufacturing system are to reduce setup times and flow times.
- Reduce inventories and market response times.
- Cells are conducive to teamwork.

Design of Cellular Manufacturing Systems

Cell Design

- Design of cellular manufacturing systems is a complex exercise with broad implications for an organization.

- The cell design process involves issues related to both system structure and system operation.

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Design of Cellular Manufacturing Systems

Structural issues include:

- Selection of part families and grouping of parts into families.
- Selection of machine and process populations and grouping of these into cells
- Selection of tools, fixtures, and pallets
- Selection of material-handling equipment
- Choice of equipment layout

Design of Cellular Manufacturing Systems

Issues related to procedures include:

- Detailed design of jobs
- Organization of supervisory and support personnel around the cellular structure
- Formulation of maintenance and inspection policies
- Design of procedures for production planning, scheduling, control, and acquisition of related software and hardware.
- Modification of cost control and reward systems
- Outline of procedures for interfacing with the remaining manufacturing system (in terms of work flow and information, computer controlled or not)

Evaluation of Cell Design Decisions

Typical considerations related to system structure include:

1. Equipment and tooling investment (low)
2. Equipment relocation cost (low)
3. Inter-and intracell material-handling costs (low)
4. Floor space requirements (low)
5. Extent to which parts are completed in a cell (high)
6. Flexibility (high)

Evaluation of Cell Design Decisions

A few typical performance variables related to system operation are:

1. Equipment utilization (high)
2. Work-in-process inventory (low)
3. Queue lengths at each workstation (short)
4. Job throughput time (short)
5. Job lateness (low)

Evaluation of Cell Design Decisions

- A major problem throughout the cell design process is the necessity of trading off against each other objectives related to structural parameters and performance variables.

- For example, higher machine utilization can be achieved if several cells route their parts through the same machine. The drawbacks are increased queuing and control problems.

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✓ **Cell Formation Approaches-I**

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Cell Formation Approaches

- A machine of cell formation approaches have been developed.

❑ **Machine-Component Group Analysis**

- Machine-component group analysis (MCGA) is based on production flow analysis.
- In MCGA-based methods, machine-component groups are formed by permuting rows and columns of the machine-component chart in the form of a zero-one matrix.

Cell Formation Approaches

- **Production Flow Analysis**

PFA involves four stages:

Stage-1: Machine Classification. Machines are classified on the basis of operations that can be performed on them. A machine type number is assigned to machines capable of performing similar operations.

Stage-2: Checking Parts List and Production Route Information. For each part, information on the operations to be undertaken and the machines required to perform each of these operations is checked thoroughly.

Cell Formation Approaches

Stage-3: Factory Flow Analysis. This involves a micro level examination of flow of components through machines. This, in turn, allows the problem to be decomposed into a number of machine-component groups.

Stage-4: Machine-Component Group Analysis. An intuitive manual method is suggested to manipulate the matrix to form cells. However, as the problem size becomes large, the manual approach does not work. Therefore, there is a need to develop analytical approaches to handle large problems systematically.

Example

- Consider a small problem of four machines and six parts as shown in Table 12.1. Modify the matrix through row and column exchanges to form cells. The part operations to be performed on the machines are represented by 1 in the matrix; a blank means no operations.

TABLE 12.1 **Part–Machine Data for Production Flow Analysis**

Machines	*Components* 1	2	3	4	5	6
M1		1		1		1
M2		1		1		1
M3	1		1		1	
M4	1		1		1	

TABLE 12.2 **The Cells Formed after Matrix Manipulation Using PFA**

Machines	*Components* 2	4	6	1	3	5
M1	1	1	1			
M2	1	1	1			
M3				1	1	1
M4				1	1	1

Rank Order Clustering Algorithm

- Rank order clustering (ROC) (King, 1980) is a simple algorithm used to form machine-part groups.

- The algorithm, which is based on sorting rows and columns of the machine-part incidence matrix, is given below:

Step-1: Assign binary weight and calculate a decimal weight for each row and column using the formulas

Decimal weight for row i = $\sum_{p=1}^{m} b_{ip}\ 2^{m-p}$

Decimal weight for column j = $\sum_{p=1}^{n} b_{pj}\ 2^{n-p}$

Step-2: Rank the rows in order of decreasing decimal weight values.

Step-3: Repeat steps 1 and 2 for each column.

Step-4: Continue preceding steps until there is no change in the position of each element in each row and column.

Example

- Consider the machine-component matrix in Table 12.3. Use the ROC algorithm to form machine cells.

TABLE 12.3 **Machine–Component Matrix**

	Components									
Machines	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
M1	1	1	1	1	1		1	1	1	1
M2		1	1	1					1	1
M3	1				1	1	1			
M4		1	1	1				1	1	1
M5	1	1	1	1	1	1	1	1		

Solution

Use the steps of the ROC algorithm

Step-1: For each row of the machine-component matrix, assign binary weights and calculate decimal equivalents as given in the following matrix (Table 12.4).

Step-2: Arranging rows by sorting the decimal weights in decreasing order results in matrix given in Table 12.5

Step-3: Repeat steps 2 and 3 for columns results in the matrix given in Table 12.6

Step-4: There is no change in the row and column positions with further iterations.

Solution

Table 12.4 Decimal Equivalents for Each Row

Machines	Components										Decimal Equivalents
	1	2	3	4	5	6	7	8	9	10	
	Binary Weights										
	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
M_1	1	1	1	1	1		1	1	1	1	1007
M_2		1	1	1					1	1	451
M_3	1				1	1	1				568
M_4		1	1	1				1	1	1	455
M_5	1	1	1	1	1	1	1	1			1020

Solution

Table 12.5 Row Arrangements for Decreasing Order of the Decimal Weights

Machines	Binary Weights	Components									
		1	2	3	4	5	6	7	8	9	10
		Binary Weights									
		2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
M_1	2^4	1	1	1	1	1	1	1	1		
M_2	2^3	1	1	1	1	1		1	1	1	1
M_3	2^2	1				1	1	1			
M_4	2^1		1	1	1				1	1	1
M_5	2^0		1	1	1					1	1
Column Decimal Equivalent		28	27	27	27	28	20	28	26	11	11

Solution

Table 12.6 One Solution for the Example using ROC Algorithm

Machines	Binary Weights	Components										Row Decimal Equivalent
		1	2	3	4	5	6	7	8	9	10	
		Binary Weights										
		2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
M_1	2^4	1	1	1	1	1	1	1	1			1020
M_2	2^3	1	1	1	1	1	1	1		1	1	1019
M_3	2^2	1	1	1					1			900
M_4	2^1				1	1	1	1		1	1	123
M_5	2^0				1	1	1			1	1	115
Column Decimal Equivalent		28	27	27	27	28	20	28	26	11	11	

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✓ **Cell Formation Approaches-II**

Cell Formation Approaches

Other Sorting Algorithms

- A number of sorting algorithms have been developed.
- A direct clustering algorithm.
- Other algorithms that offer improvements over ROC include MODROC.

Cell Formation Approaches

Similarity Coefficient-Based Approaches

- In similarity coefficients methods, the basis is to define a measure(s) of similarity between machines, tools, design features, and so forth and then use it to form part families and machine groups.
- A number of methods have been developed, such as single-linkage cluster analysis (McAuley, 1972), average-linkage method (Seifoddini and Wolfe, 1986), complete linkage, centroid, and median methods (Mosier, 1989), MACE (Waghodekar and Sahu, 1984), cluster identification algorithm (Kusiak and Chow, 1987), and mathematical classification).

TABLE 12.4 Decimal Equivalents for Each Row

	Components										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	
	Binary weight										
Machines	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	*decimal equivalent*
M_1	1	1	1	1	1		1	1	1	1	1007
M_2		1	1	1					1	1	451
M_3	1				1	1	1				568
M_4		1	1	1				1	1	1	455
M_5	1	1	1	1	1	1	1	1			1020

TABLE 12.5 Row Arrangement in Decreasing Order of the Decimal Weights

		Components									
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
		Binary weight									
Machines	*Binary weight*	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
M_5	2^4	1	1	1	1	1	1	1	1		
M_1	2^3	1	1	1	1	1		1	1	1	1
M_3	2^2	1				1	1	1			
M_4	2^1		1	1	1				1	1	1
M_2	2^0		1	1	1					1	1
Column decimal equivalent		28	27	27	27	28	20	28	26	11	11

TABLE 12.6 **One Solution for the Example Using ROC Algorithm**

Machines	Binary weight	Components: 1	5	7	2	3	4	8	6	9	10	
		Binary weight: 2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	Row decimal equivalent
M_5	2^4	1	1	1	1	1	1	1	1			1020
M_1	2^3	1	1	1	1	1	1	1		1	1	1019
M_3	2^2	1	1	1					1			900
M_4	2^1				1	1	1	1		1	1	123
M_2	2^0				1	1	1			1	1	115
Column decimal equivalent		28	28	28	27	27	27	26	20	11	11	

Single-Linkage Cluster Analysis

- Single-Linkage cluster analysis (SLCA) uses similarity coefficients between machines.
- The procedure is to construct a tree called a dendrogram. Similarity coefficients between machines are used to construct the dendrogram.
- The similarity coefficients between two machines is defined as the ratio of the number of parts visiting both machines and the number of parts visiting one of the two machines as follows:

Single-Linkage Cluster Analysis

- $S_{ij} = \frac{\sum_{k=1}^{N} X_{ijk}}{\sum_{k=1}^{N}(Y_{ik}+Z_{jk}+X_{ijk})}$

where,

- X_{ijk} = operation on part *k* performed both on machine *i*and *j*,
- Y_{ik} = operation on part *k* performed on machine *i*,
- Z_{jk} = operation on part *k* performed on machine *j*.

SLCA Algorithm

- The steps of the algorithm are as follows:

- **Step-1:** Compute similarity coefficients for all possible pairs of machines.
- **Step-2:** Select the two most similar machines to form the first machine cell.
- **Step-3:** Lower the similarity level (threshold) and form new machine cells by including all the machines with similarity coefficients not less than the threshold value.
- **Step-4:** Continue step 3 until all the machines are grouped into a single cell.

Example

- Consider the matrix of 5 machines and 10 components given in Table 12.3. Develop a dendrogram and discuss the resulting cell structures.

TABLE 12.3 **Machine–Component Matrix**

	Components									
Machines	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
M1	1	1	1	1	1		1	1	1	1
M2		1	1	1					1	1
M3	1				1	1	1			
M4		1	1	1				1	1	1
M5	1	1	1	1	1	1	1	1		

Solution

- The steps of the algorithm are as follows:

- **Step-1:** Determine the similarity coefficients between all pairs of machines. The similarity coefficient between machine 1 and machine 2 is determined as follows:

$$SC_{12} = \frac{5}{9+5-5} = 0.556$$

- Similarly, other similarity coefficients are calculated and are given in Table 12.7

Example

TABLE 12.7 Similarity Coefficients for the Problem Data Given in Table 12.3

Machine pair:	M1 M2	M1 M3	M1 M4	M1 M5	M2 M3	M2 M4	M2 M5	M3 M4	M3 M5	M4 M5
Similarity coefficient:	0.55	0.30	0.67	0.70	0.00	0.83	0.30	0.00	0.50	0.40

- **Step-2:** Select machines M2 and M4, having the highest similarity coefficient of 0.83, to form the first cell.
- **Step-3:** The next lower coefficient of similarity is between machines M1 and M5. Use these to form the second cell.

Solution

- **Step-4:** The next lower coefficient is now 0.67 between machines M1 and M4. At this threshold value machines M1, M2, M4, and M5 will form one machine group. The next lower coefficient of similarity is 0.55 between machines M1 and M2, which is dominated by the similarity coefficient of 0.67 (for example, see Figure 12.5). The lower nondominated similarity coefficient is 0.50 between machines M3 and M5, at which all the machines belong to one cell.

Solution

- The dendrogram constructed using the similarity coefficient data given in Table 12.7 in Figure 12.5. Cells can be identified at different threshold values by drawing a horizontal line at that value. For example, for cells {(M2, M4), (M5), (M1), (M3)} will be formed at a threshold value of 0.80, whereas only one cell is formed at a threshold value of 0.40.

Example

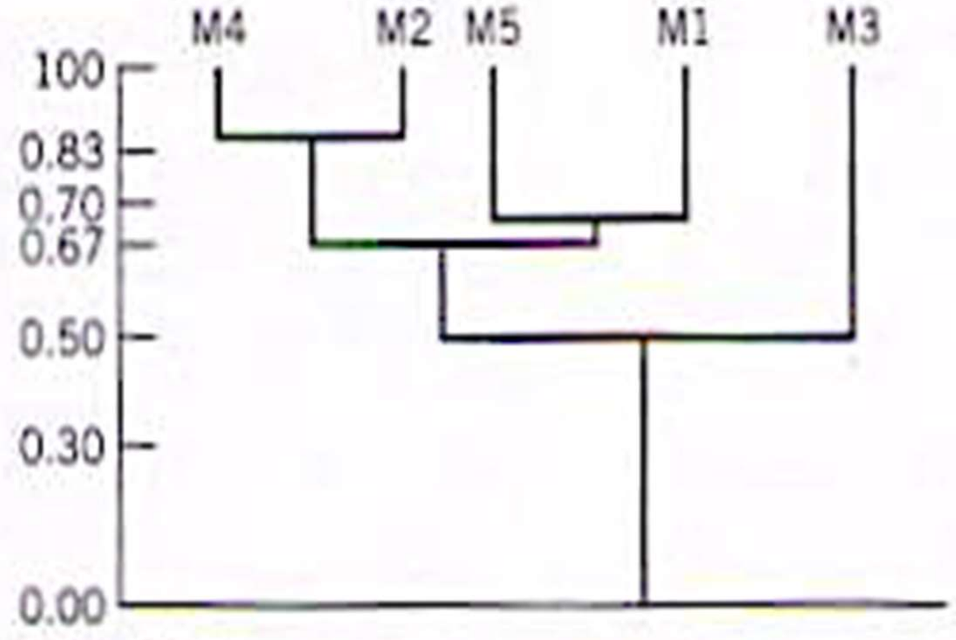

FIGURE 12.5 The dendrogram for the data of Example 12.5.

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✓ **Evaluation of Cell Design, Numerical Examples**

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Exceptional Parts and Bottleneck Machines

- The creation of mutually independent machine cells with no intercell movement is one of the important goals of cell design.

- However, it may not always be economical or practical to achieve mutually independent cells. In practice, therefore, some parts need to be processed in more than one cell.

- These are known as “exceptional” parts and the machines processing them are known as “bottleneck” machines.

Exceptional Parts and Bottleneck Machines

- The problems of exceptional elements:
  a) Generating alternative process plans
  b) Duplication of machines
  c) Subcontracting these operations

- However, a solution will depend very much on the nature of the operations involved. A number of analytical methods have been suggested in the literature to help resolve the problem of exceptional elements and bottleneck machines.

Evaluation of Cell Designs

- In Example 12.5, we notice from the dendrogram that four, three, two, and one cells are formed at similarity coefficients of 0.83, 0.70, 0.67, and 0.50, respectively.

- Also, five cells will be formed if each machine is treated as an independent cell resulting in a similarity coefficient of 1.

- These cell configurations are shown in Table 12.8.

Evaluation of Cell Designs

TABLE 12.8 Alternative Cell Configurations

Similarity coefficient	*Number of cells formed*	*Cell configuration*
1.00	5	(M1), (M2)*, (M3), (M4), (M5)
0.83	4	(M2, M4), (M5), (M1), (M3)
0.70	3	(M2, M4), (M1, M5), (M3)
0.67	2	(M1, M2, M4, M5), (M3)
0.50	1	(M1, M2, M3, M4, M5)

* Each set of parentheses (,) designates a cell.

Evaluation of Cell Designs

- A number of criteria can be used to decide on the optimal cell configuration.
- To choose a cell design from a set of alternatives, a criterion of minimizing the total material-handling cost of intercell (between cells) and intracell (within cell) movements of parts is particularly relevant if parts have a number of operations visiting a number of machines.

Evaluation of Cell Designs

- Following factors influence these costs of inter- and intracell moves:
  a) The layout of machines in a group
  b) The layout of machine groups
  c) The sequence of parts through machines and machine groups.
- The total distances moved by a component visiting a number of machines in a cell has to determined.
- Analytical expressions for the total expected distances moved can be determined if machines in a cell are laid out in (1) straight line, (2) a rectangle or (3) a square.

Evaluation of Cell Designs

Following reasonable assumptions are made:

1. In the absence of real data on the sequences in which the components visit the machines, it is assumed that the machines are laid out in a random manner.

2. There is one unit distance between each machine in a group of N machines.

3. A part has to visit two machines in a group of N machines

Evaluation of Cell Designs

Expected distance a part moves between two machines in a cell having a group of N machines can be shown to be:
Expected distance for a straight-line layout = (N+1)/3
Expected distance for a rectangle layout with M rows of L machines = M+L/3
Expected distance for a square layout = $2\frac{\sqrt{N}}{3}$
Total distance moved in jth cell for the ith configuration = $\sum^{m}_{j} d_{ij}k_{ij}$

where d_{ij} = expected distance moved between two machines for ith configuration in jth cell

Evaluation of Cell Designs

K_{ij} = number of moves between two machines by all parts for ith configuration in jth cell

m = total number of cells

The total cost of inter- and intracellular movements (Tc_i) for the ith configuration: $Tc_i = C_1 N_i + C_2 \sum^m_j d_{ij} k_{ij}$

Where C_1 = cost of an intercell movement, C_2 = cost per unit distance of an intracell movement, and N_i = number of intercell movements for ith configuration

We now illustrate the calculation of intercell moves and intracell expected distance for the cell configuration [(M1, M5), (M2, M4), (M3)] as shown in Table 12.9.

TABLE 12.9 Cell Design with Three Cell Configuration

Machines	Components									
	1	5	2	3	4	7	8	9	10	6
M1	1	1	1	1	1	1	1	1	1	
M5	1	1	1	1	1	1	1			1
M2			1	1	1			1	1	
M4			1	1	1		1	1	1	
M3	1	1				1				1

Evaluation of Cell Designs

- The number of moves passing through two machines by all the parts in a cell (M_1, M_5) is seven. In cell (M_2, M_4) there are five moves (two for parts 9 and 10 within the cell and three for parts 2,3, and 4 outside the cell but processed within the cell). In cell (M_3), there are zero moves, since there is only one machine.
- Total distance for all intracell moves assuming straight line layout

  $$= (2+1/3)7 + (2+1/3)5 + 0 = 12$$

- The number of intercell moves is 10 for this cell configuration. Assuming C_1 = \$2.00 and C_2 = \$1.00, the total cost of intercell and intracell moves for all the solutions is given in Table 12.10

TABLE 12.10 **Cell Configurations and Their Analysis of Intercell Moves, Intracell Moves, and Total Cost Assuming Straight Line Layout**

	Cell Configuration	*Number of Intercell Moves*	*Total Distance of Intracell Moves*	*Total Cost of Intercell and Intracell Moves*
5-cells	(M1), (M2)*, (M3), (M4), (M5)	22	0	$2 \cdot 22 + 1 \cdot 0 = 44$
4-cells	(M2, M4), (M5), (M1), (M3)	17	5	$2 \cdot 17 + 1 \cdot 5 = 39$
3-cells	(M2, M4), (M1, M5), (M3)	10 ✓	12 ✓	$2 \cdot 10 + 1 \cdot 12 = 32$
2-cells	(M1, M2, M4, M5), (M3)	4	30	$2 \cdot 4 + 1 \cdot 30 = 38$
1-cell	(M1, M2, M3, M4, M5)	0	44	$2 \cdot 0 + 1 \cdot 44 = 44$

* Each set of parentheses (,) designates a cell.

Cellular Manufacturing System

✓ **Production Planning and Control in CMS**

An Alternative Approach to Evaluating Goodness of Heuristic Solutions

- The heuristic algorithms used for forming part families and machine cells essentially try to rearrange the rows and columns of the matrix to get a block diagonal form.
- The ideal situation is to have all ones in the diagonal block and zeros in the off-diagonal blocks.
- However, the block diagonal form is usually far from ideal because of the properties of the data, the inadequacies of the algorithm, or both.
- It is therefore important to have some measure of goodness of the solution obtained by any algorithm.

An Alternative Approach to Evaluating Goodness of Heuristic Solutions

- Kumar and Chandrasekharan (1990) have developed an alternative quantitative criterion for evaluating the goodness of block diagonal forms of binary matrices, called **grouping efficacy**.

- This measure is particularly useful in the absence of information on the physical layout of machines in the cell and the cost of inter- and intracellular material handling.

An Alternative Approach to Evaluating Goodness of Heuristic Solutions

- The grouping efficacy (Γ) is defined as

$$\Gamma = \frac{1-\psi}{1+\phi}$$

- where,

$$\psi = \frac{\text{number of exceptional elements}}{\text{total number of operations}}$$

An Alternative Approach to Evaluating Goodness of Heuristic Solutions

$$\phi = \frac{\text{number of voids in the diagonal blocks}}{\text{total number of operations}}$$

An analysis of the grouping efficacy reveals the following:

- An increase in intercell movements or voids or both will lead to a reduction in grouping efficacy.

An Alternative Approach to Evaluating Goodness of Heuristic Solutions

- Change in the number of exceptional elements has a greater influence than change in the number of voids in the diagonal blocks.
- At lower efficacies, the voids in the diagonal blocks become less and less significant.

- It is worth mentioning here that the grouping efficacy-based approach may yield a different cell configuration than that suggested by the cost model.

Numerical Example-1

- Consider the machine-component data given in Table 1. Further, consider the three solutions with two-, three-, and four-cell configurations obtained using the single-linkage cluster analysis approach and given in Table 2. Calculate the grouping efficacy values for these cell configurations. Recommend a solution based on the grouping efficacy criterion.

Numerical Example-1

Table 1. Machine-Component Matrix

Machines	Components									
	1	2	3	4	5	6	7	8	9	10
M1	1	1	1	1	1		1	1	1	1
M2		1	1	1					1	1
M3	1				1	1	1			
M4		1	1	1				1	1	1
M5	1	1	1	1	1	1	1	1		

Numerical Example-1

Table 2. Cell Configurations and Their Analysis of Intercell Moves, Intracell Moves, and Total Cost Assuming Straight Line Layout

Cell Configuration		Number of Intercell Moves	Total Distance of Intracell Moves	Total Cost of Intercell and Intracell Moves
5-cells	(M1), (M2)*, (M3), (M4), (M5)	22	0	2.22 + 1.0 = 44
4-cells	(M2, M4), (M5), (M1), (M3)	17	5	2.17 + 1.5 = 39
3-cells	(M2, M4), (M1, M5), (M3)	10	12	2.10 + 1.12 = 32
2-cells	(M1, M2, M4, M5), (M3)	4	30	2.4 + 1.30 = 38
1-cell	(M1, M2, M3, M4, M5)	0	44	2.0 + 1.44 = 44

Solution

- Three-cell configuration:

$$\Gamma = \frac{1 - 13/32}{1 + 0/32} = 0.59375$$

- Four-cell configuration:

$$\Gamma = \frac{1 - 17/32}{1 + 0/32} = 0.46875$$

- The highest efficacy value is for the three-cell configuration. Therefore, the recommendations based on grouping efficacy is to have a cell design with three cells.

Economics of Group Tooling in Cellular Manufacturing

- One of the objectives in cell formation is to group parts into part families required similar tooling.
- This design reduce the setup time and cost.
- In processing a part family, a group fixture and a couple of adapters are required, which are much cheaper than the number of fixtures required in a conventional manufacturing situation.
- For the purpose of cost comparison, we present the following analysis from Mitrofanov (1966) and Ham et al, (1985):

Economics of Group Tooling in Cellular Manufacturing

❑ Conventional Tooling Method

- The unit cost of conventional tooling (UCC) using *p* different jigs or fixtures can be written as

$$UCC = \frac{1}{n}\left(\sum_{i=1}^{p} C_i\right)$$

- where C_i is the cost of a jig or a fixture and *p* is the number of different fixtures used to produce *n* parts.

Economics of Group Tooling in Cellular Manufacturing

- **Group Tooling Method**

- The unit cost of group tooling (UCG) is given by

$$UCC = \frac{1}{n}\left(\sum_{j=1}^{q} C_j + C_g\right)$$

- where C_j is the cost of an adapter, q different types of adapters are required, and C_g is the cost of a group fixture.

Economics of Group Tooling in Cellular Manufacturing

- Normally, the cost of an adapter is much less than that of a fixture in conventional tooling.

- It is therefore obvious from these relations that group tooling would become more economical with an increase in the number of parts in the family.

Production Planning and Control in Cellular Manufacturing Systems

- Cellular manufacturing systems have certain characteristics that make the production planning problems different from those in traditional production systems.
- For example:
  1. Use of group tooling considerably reduces setup time.
  2. Machines are more flexible in performing various operations.
  3. Low demands and large variety of parts.
  4. Fewer machines than part types.

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Production Planning and Control in Cellular Manufacturing Systems

- These characteristics alter the nature of production planning problems in GT-cellular manufacturing systems and permit us to take advantage of similarities of setups and operations by integrating GT concepts with material requirements planning (MRP).
- In an MRP-based system, optimal lot sizes are determined for various parts required for products.
- However, similarities among the parts requiring similar setups and operations are not exploited.

Production Planning and Control in Cellular Manufacturing Systems

- The grouping of the parts for loading and scheduling based on similar setups and operations will reduce setup time.
- On the other hand, the time-phased requirement planning aspect is not considered in GT.
- That is, all the parts in a group are assumed to be available at the beginning of the period.
- Integration of GT and MRP will lead to a better production planning and control system.

List of Reference Textbooks

- Groover, M P, Automation, Production Systems, and Computer Integrated Manufacturing, Third Edition, Pearson Prentice Hall, Upper Saddle River.
- Groover, M P and Zimmers, E W Jr, CAD/CAM: Computer-aided Design and Manufacturing, Prentice-Hall of India Private Ltd.
- Rao, V D and Ray, P K, Product and Process Design for Quality, Economy and Reliability, New Age.

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Thank You!!