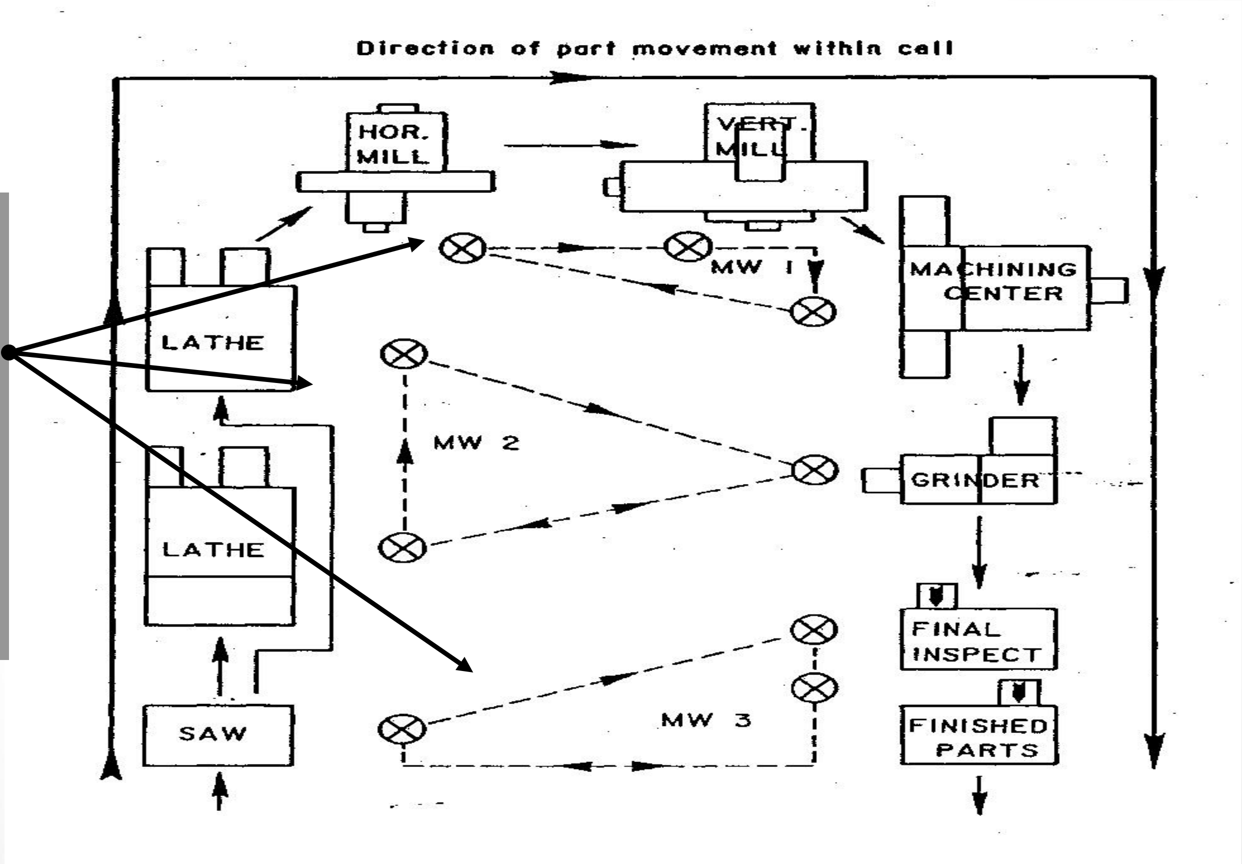
Cellular Manufacturing Systems

CMS and its relationship to Job and Flow Shops:

- We can define the movement in a Job Shop (mathematically) this way for any product i:
  - $Pr(1 \rightarrow 2)_i = Pr(1 \rightarrow 3)_i = Pr(1 \rightarrow 4)_i = \ldots = Pr(1 \rightarrow n)_l$
- While in a Flow Shop:
  - $Pr(1 \rightarrow 2)_i = 1$ and $Pr(1 \rightarrow n)_i = 0$ (n   2)
- In developing CMS manufacturing systems we are trying to make all part flows act like Flow shop mathematics!

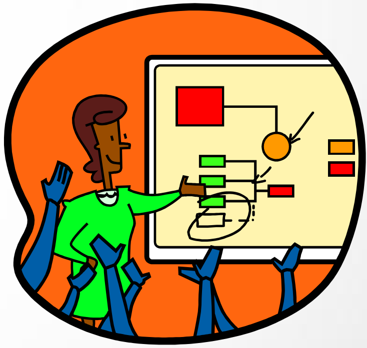
Examining a Cell in the CMS:

Notice MW or 'multi-functional' workers – this team is responsible for all production within their cell

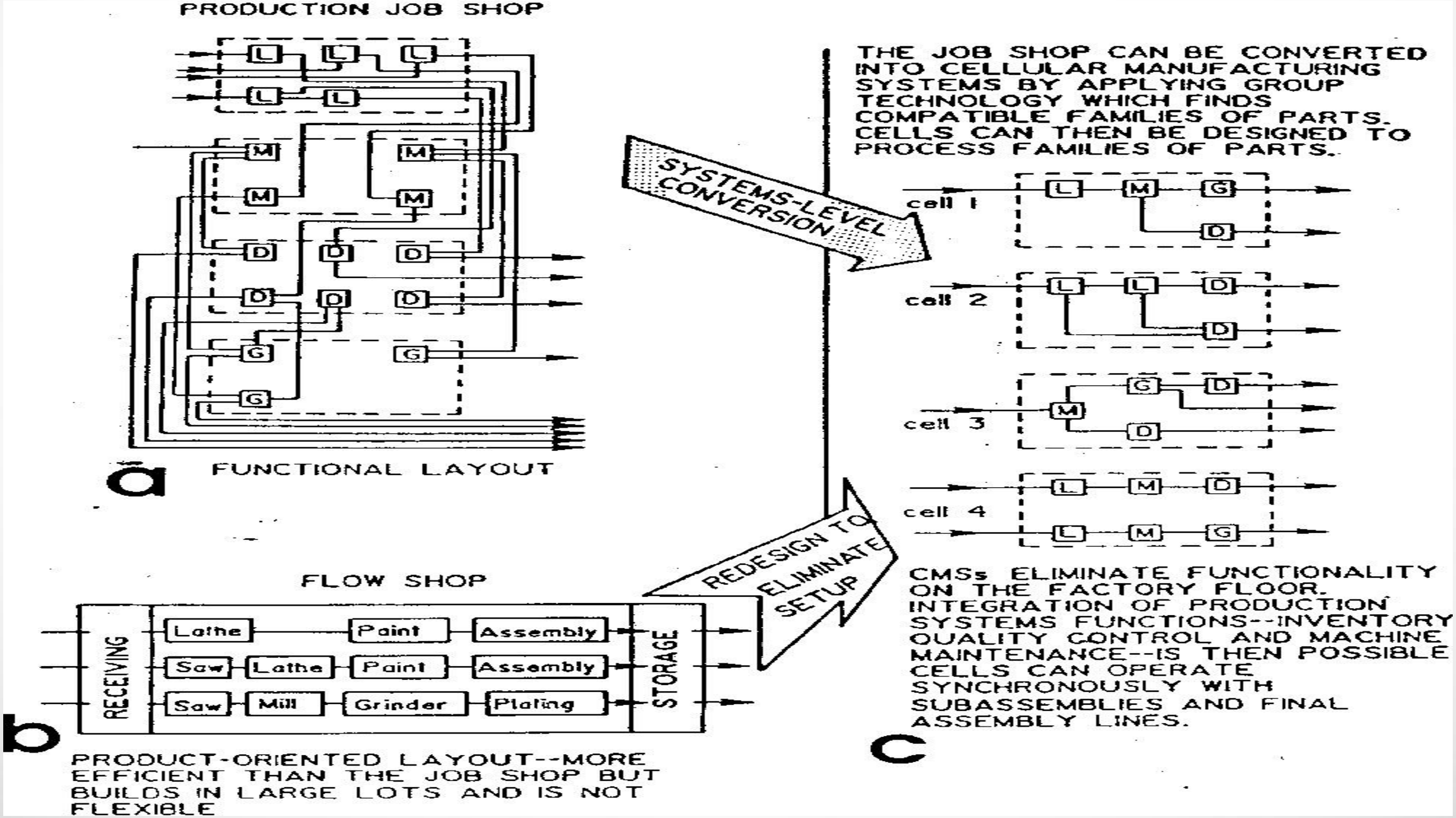


CMS and Group Technology (GT)

- CMS layout are based on recognizing similarities in products – similarities in geometry, size, materials and processing requirements
- This similar products are collected – “Grouped” instead of being treated as individuals
- Leads to product families that visit similar equipment and populate their ‘cells’ production schedule
- Simpler setups like in a Job shop can follow and the workers become multifunctional and responsible for all aspects of a product – and its quality
- Cells can be scheduled to produce synchronously bringing the various sub-assemblies in as needed at final assembly with greater variety built in

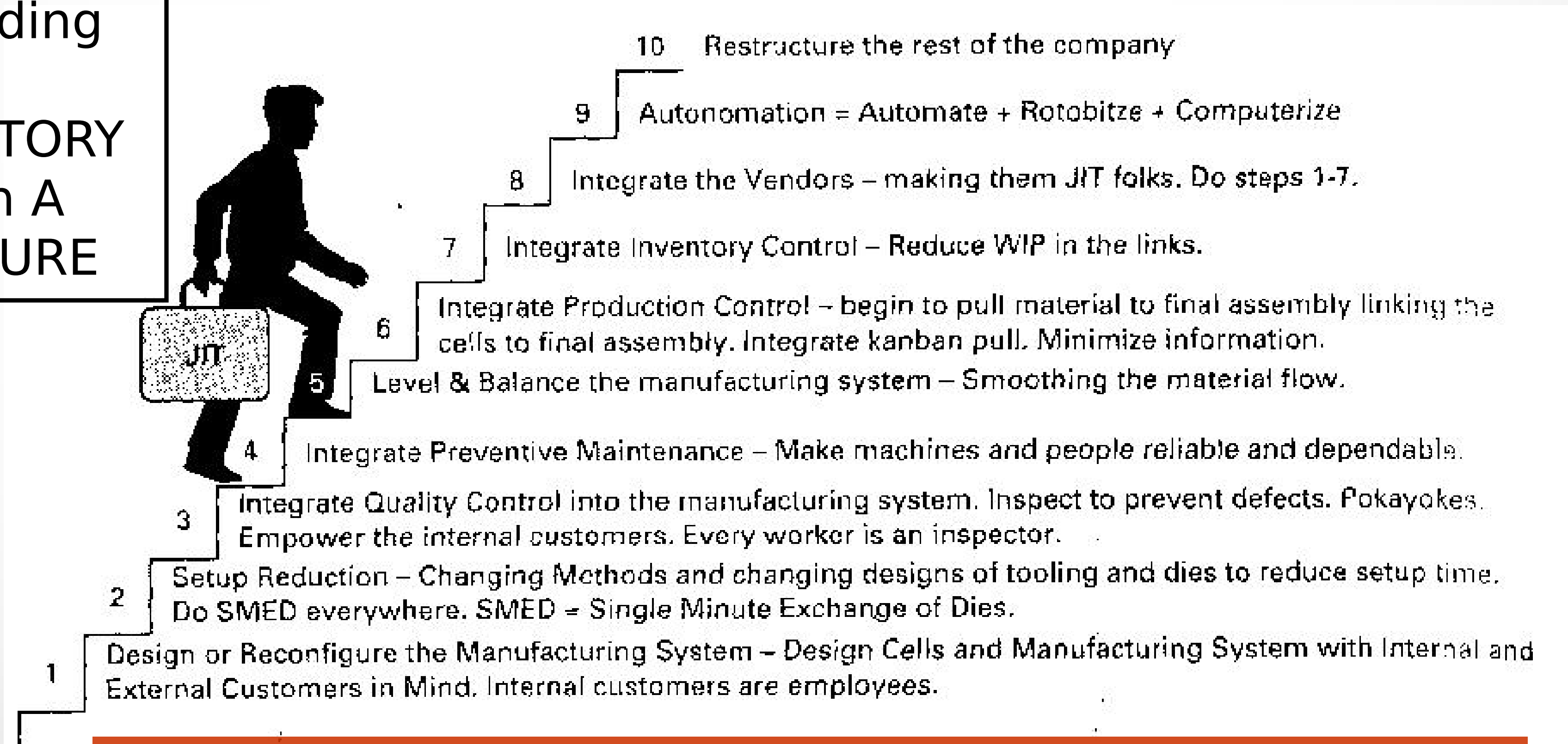


CMS and Group Technology (GT)



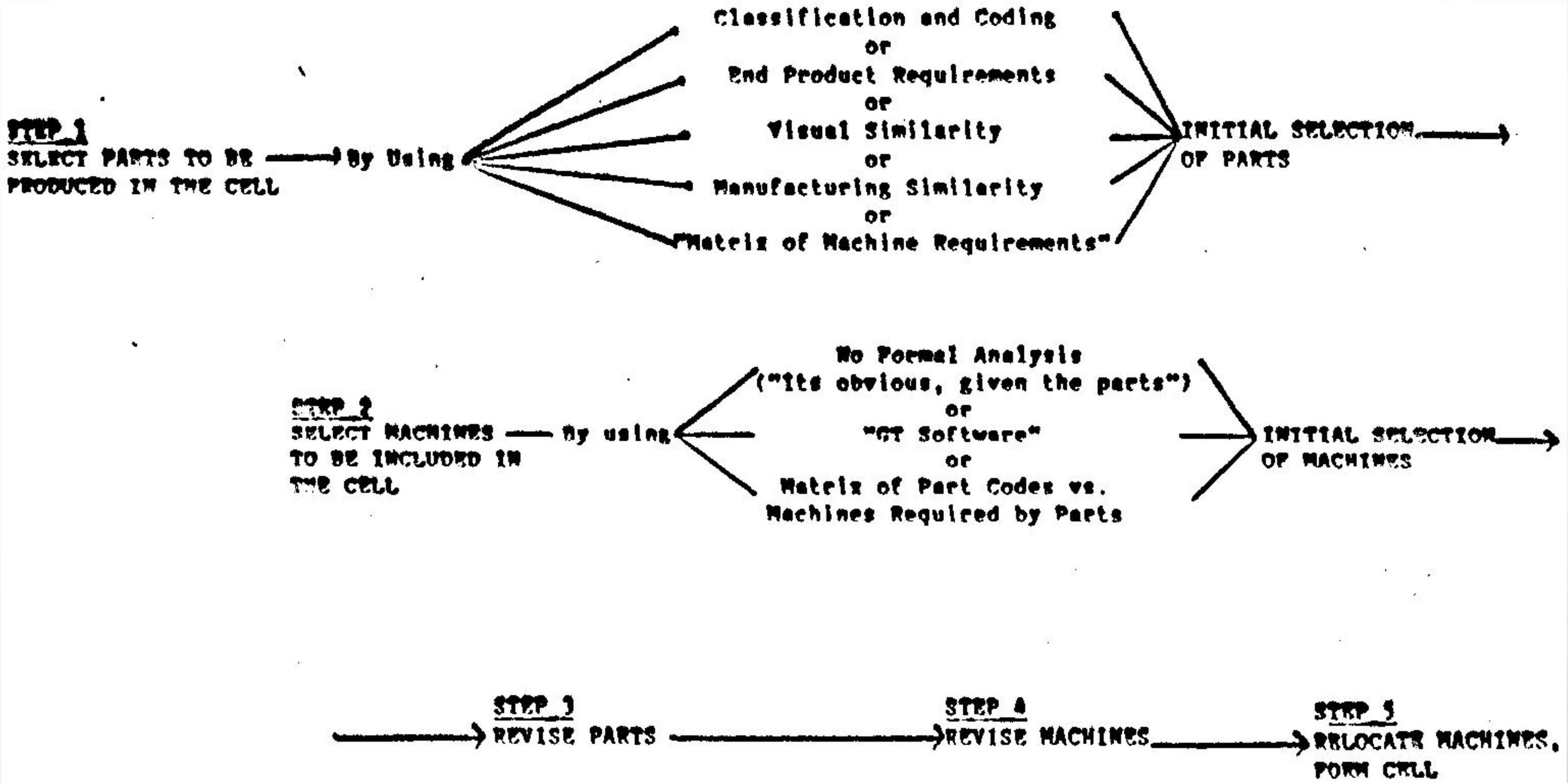
CMS and Group Technology (GT)

Building the FACTORY With A FUTURE



NOTE: Step 1 is CMS – a fundamental action in LEAN MFG'ing

CMS and Group Technology (GT)



Benefits of GT and CMS (Companies Reporting):

- 52% Report reduction in new part design
- 10% Report reduction in # of new drawings thru standardization
- 30% Report reduction in new shop drawings
- 60% Report reduction in IE time
- 20% Report reduction in floor space
- 45% Report reduced scrap
- 80% Report reduced production and quality costs
- 69% Report reduced set-up time (cost)

Note: ‘Reported’ by companies in a survey of adopters of GT

Benefits of GT and CMS (Companies Reporting):

- 70% Report reduced throughput time (even more report better predictability of delivery)
- 82% Report reduced numbers of overdue orders
- 42% Report reduced raw-materials inventory
- 62% Report reduced WIP
- 60% Report reduced finished goods inventory
- 33% Report increased employee output/time unit (productivity improvement)

Clustering Techniques: the Fundamental Issue in Cell Development

We cluster parts to build part families

- Part Families visit cells
- Part Families share set-up ideas and equipment (Family Fixtures)
- Part Families follow the same (or similar) process routing
- These are the ideas and activities that offer reported benefits

Clustering Techniques: the Fundamental Issue in Cell Development

- We cluster Machines to build cells:
  - Cells lead to Flow Mathematics
  - Cells contain all equipment needed to produce a part family
  - Cells allow development of Multi-functional workers
  - Cells hold work teams responsible for production and quality “They Empower” the workers
    - Empowered to set internal schedules
    - Empowered to assign tasks
    - Empowered to train and rotate jobs
    - Etc

Building the CMS Facility

Before Clustering

Job number	A	B	C	D	E	F	G	H	I	J
1								X		
2		X	X							
3				X						
4							X	X		
5	X	X	X							
6									X	X
7	X		X							
8						X		X		
9									X	X
10				X	X					
11	X	X	X						X	
12						X	X			
13									X	
14				X	X					
15									X	X
16		X				X	X	X		
17										X
18	X	X								
19						X	X	X		
20					X					

A matrix of jobs (by number) and machine tools (by code letter) as found in the typical job shop.

After Clustering

Job number	A	B	C	D	E	F	G	H	I	J
7	X		X							
11	X	X	X					X (exception)		
2		X	X							
5	X	X	X							
18	X	X								
14				X	X					
3				X						
10				X	X					
20										
12						X	X			
4							X	X		
19						X	X	X		
16						X	X	X		
8						X		X		
1								X		
9			X (exception)						X	X
13									X	
6									X	X
15									X	X
17										X

Cell will have 3 machines F, G, H, for manufacture of 6 jobs.

A matrix rearranged to yield families of parts and associated groups of machines that can form a cell.

Clustering Methods

- Using Process Similarity methods:
  - Create Machine – Part Matrices
  - Compute machine ‘pairwise’ Similarity Coefficient comparisons:

$$S_{ij} = \frac{x_{ij}}{\left(x_{ij} + x_{jj}\right)}$$

here:

x_{ij} **is # of parts (in matrix) visiting**

both machines of the pair

x_{jj} **is # of parts visiting one but not both machines**

Example:

	Part ‘Number’						
Machine ID	X	1	2	3	4	5	6
	A			1		1	
	B		1	1			
	C	1			1		
	D		1	1		1	
	E	1			1		1

Computing Similarity Coefficients:

- Total Number is:
  - [(N-1)N]/2 = [(5-1)5]/2 = 10
  - For 25 machines (typical number in a small Job Shop): 300 S_{ij}'s
- Here they are:

$$S_{AB} = \frac{1}{1+2} = .33$$

$$S_{AC} = \frac{0}{0+4} = 0$$

$$S_{AD} = \frac{2}{2+1} = .67$$

Continuing:

- Here, if the similarity coefficient is 0 .33 consider clustering
- This criteria means clustering:
    - A&D, A&B, B&D
    - C & E
- Declustering:
    - A&C, A&E, B&C, B&E and C&D, D&E

$$S_{AE} = \frac{0}{0+5} = 0$$

$$S_{BC} = \frac{0}{0+4} = 0$$

$$S_{BD} = \frac{2}{2+1} = .67$$

$$S_{BE} = \frac{0}{0+5} = 0$$

$$S_{CD} = \frac{0}{0+5} = 0$$

$$S_{CE} = \frac{2}{2+1} = .67$$

$$S_{DE} = \frac{0}{0+6} = 0$$

Continuing:

- Examining our Matrix and our freshly clustered 'machine cells,' we develop 2 part families:
    - For the Cell A/D/B: Part Numbers 2, 3 & 5
    - For the Cell C/E: Part Numbers 1, 4 & 6
- Care must be taken (in most cases) to assure that each cell has all the machines it needs – sometimes a couple of families need a key machine
    - In this case, the manager must decide to either replicate the common machine or share it between the cells creating a bottleneck and scheduling problem for each cell
    - This is typically one of the cost problems in CMS systems

Summarizing:

- Make Machine/Part Matrix
- Compute Similarity Coefficients
- Cluster Machines with positive (0 .33) S_{ij}'s
- Determine Part Families for the clusters (cells)
- Decide if machine replication is cost effective
- Re-layout facility and Cross Train workforce
- Start counting your new found cash
- Court customers to grow part families on Cell-by-Cell basis

Other Clustering Methods:

- Rank order Clustering
  - This method automates the cluster study by computing Binary weights from a machine – part matrix
  - It orders parts and machine cells ‘automatically’ by structuring and computing the matrix with binary weights
  - It implies a computer algorithm for solving the clustering problem
  - It may not solve if machines are needed by more than one family – forces intelligence in application and hand scanning after several ordering iterations

Rank Order Clustering Method:

1. For each row of the machine/part matrix (M/P/M) read the pattern of cell entries as a binary word. Rank the rows by decreasing binary value. Equal values stay in same order.
2. Ask if newly ranked rows in the matrix are the same as previous order? – Yes (STOP) No (continue)
3. Re-form the M/P/M with rows in new descending order. Now rank the columns by decreasing binary word weight. Columns of equal weight are left where they are
4. Are current column weights the same as current column order? Yes (STOP), No (continue)
5. Re-form the matrix column order per rank order (highest to left) and return to #1.

Lets try it with our earlier problem:

	Part 'Number'						
Machine ID	X	1	2	3	4	5	6
	A			1		1	
	B		1	1			
	C	1			1		
	D		1	1		1	
	E	1			1		1

Step 1:

		Part Numbers						D. Equiv	Rank
		1	2	3	4	5	6		
	B. Wt:	2^5	2^4	2^3	2^2	2^1	2^0		
Machine ID	A			1		1		$2^3+2^1 = 10$	5
	B		1	1				$2^4+2^3 = 24$	4
	C	1			1			$2^5+2^2=36$	2
	D		1	1		1		$2^4+2^3+2^1 = 26$	3
	E	1			1		1	$2^5+2^2+2^0=37$	1

Step 2: Must Reorder!

Step 3:

			Part Number					
		B. WT.	1	2	3	4	5	6
Machine ID	E	2^4	1			1		1
	C	2^3	1			1		
	D	2^2		1	1		1	
	B	2^1		1	1			
	A	2^0			1		1	
D. Equiv			$2^4+2^3=24$	$2^2+2^1=6$	$2^2+2^1+2^0=7$	$2^4+2^3=24$	$2^2+2^0=5$	$2^4=16$
Rank			1	5	4	2	6	3

Step 4: Must Reorder

Back at Step 1:

Great Cluster Result!

		Part Number						D. Eqv	Rank
		1	4	6	3	2	5		
B Wt:		2^5	2^4	2^3	2^2	2^1	2^0		
Machine ID	E	1	1	1				$2^5+2^4+2^3=56$	1
	C	1	1					$2^5+2^4 = 48$	2
	D				1	1	1	$2^2+2^1+2^0 = 7$	3
	B				1	1		$2^2+2^1=6$	4
	A				1		1	$2^2+2^0=5$	5

Order stays the same: STOP!

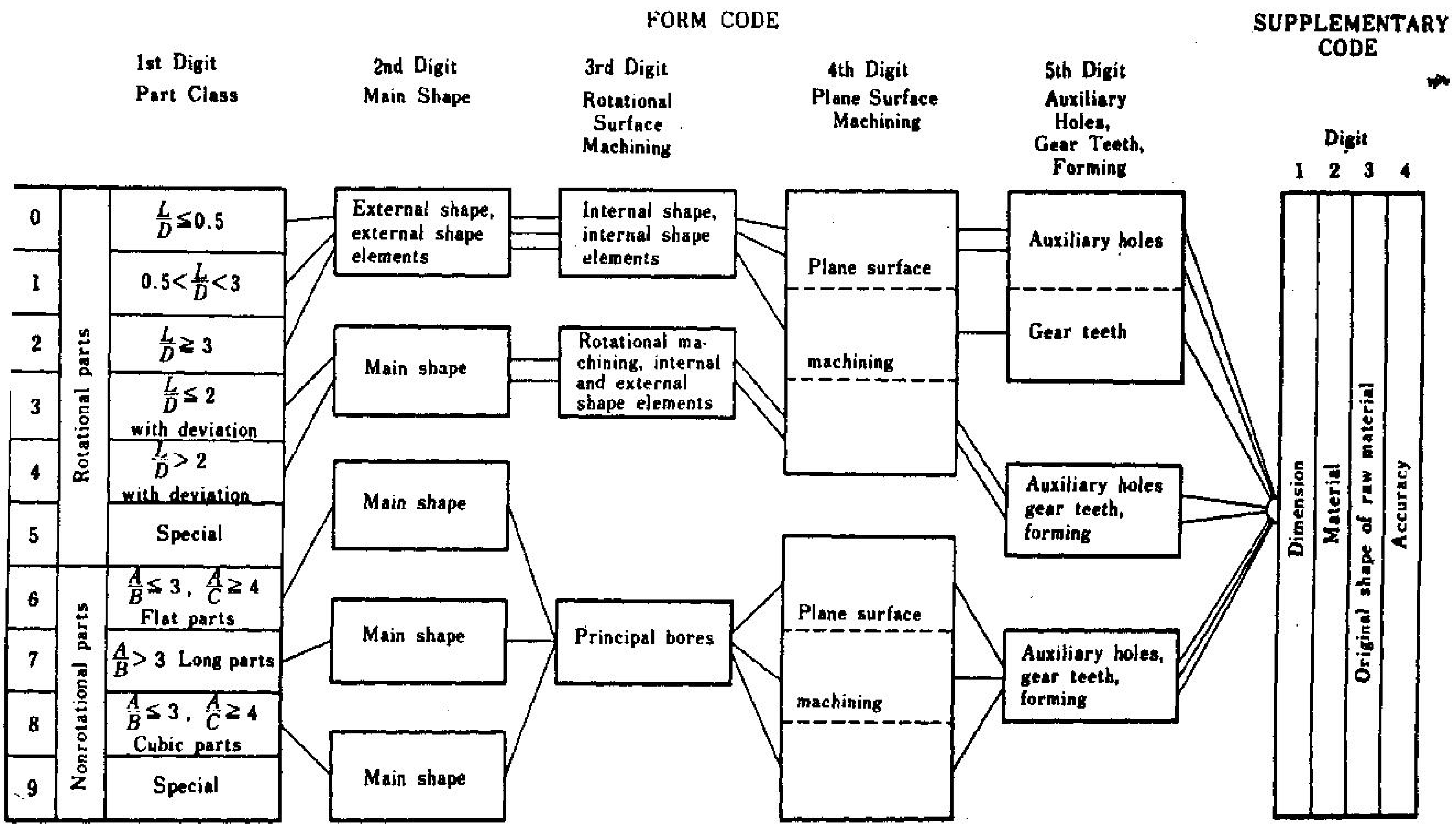
Issues in Clustering:

- R/O clustering *oscillations* indicating need of machine replication (happens often!)
- Presence of Outliers and/or Voids in the finished clusters
    - Outliers indicate the need of machine replication
    - Voids indicate ‘skipped’ machines in a cell
- Generally speaking, these clustering algorithms are designed to convert existing routes for facility re-organization
    - They require a previous engineering study to be performed to develop a series of routers on a core sample of parts that represent most of the production in the shop

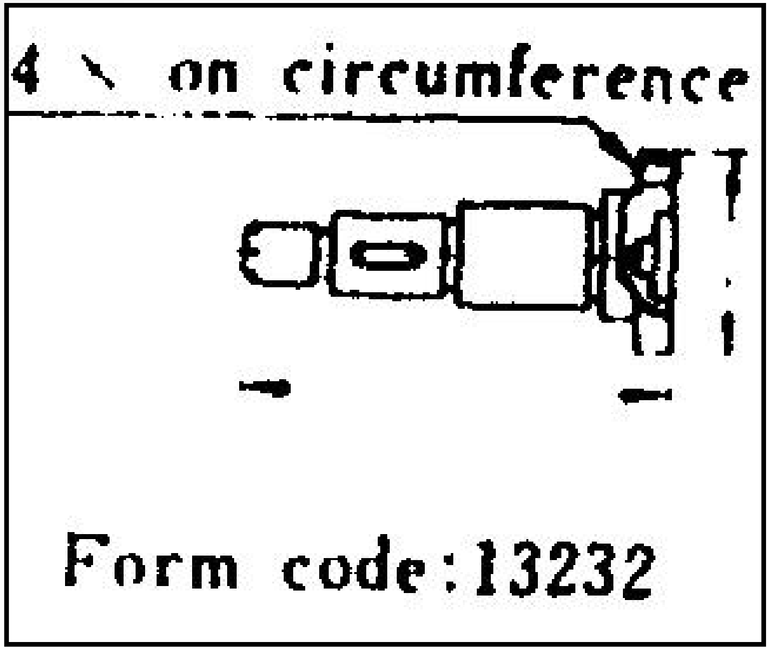
Alternative means to Develop Cells/Families:

- Most often companies rely on Classification and Coding (C&C) systems for analyzing their part mix
- These codes can be general purpose or company specific
  - General Purpose:
    - Opitz is a german developed code for machined parts (see over)
    - KC1, KC2 and KK1 systems Japanese government lab based codes for machined parts
    - Brish a british developed code for general material use
    - Foundry codes have been developed by several groups (see Lindeke & Rubinovich, 1987 in USA)

Examining Opitz Code:



Examining Opitz Code:



This Form code is the Opitz Code Solution on this shaft-like part

Examining Opitz Code:

	1st Digit	2nd Digit	3rd Digit	4th Digit	5th Digit
	Part class	External shape, external shape elements	Internal shape, internal shape elements	Plane surface machining	Auxiliary holes and gear teeth
0	Rotational parts: $\frac{L}{D} < 0.5$	No machining	No machining: Without bore, without through hole	No plane surface machining	No gear teeth: No auxiliary bore
1	Rotational parts: $0.5 < \frac{L}{D} < 3$	Smooth, no shape elements	No machining: With through hole	External plane surface and or surface curved in one direction	No gear teeth: Axial holes without indexing
2		Stepped to one end or smooth: No shape elements	Stepped to one end or smooth: No shape elements	External plane surfaces related to one another with a pitch	No gear teeth: Axial holes with indexing
3		Stepped to one end or smooth: Screwthread	Stepped to one end or smooth: Screwthread	External groove and or slot	No gear teeth: Axial and or radial holes and or in other directions
4		Stepped to one end or smooth: Functional groove and or functional taper (and screw thread)	Stepped to one end or smooth: Functional taper (radial groove) (and screw thread)	External spline (polygon)	No gear teeth: Axial and or radial holes with indexing and or in other directions
5		Stepped to both ends (multiple increases): No shape elements	Stepped to both ends (multiple increases): No shape elements	External spline, slot and or groove	Spur gear teeth without auxiliary holes
6		Stepped to both ends (multiple increases): Screwthread	Stepped to both ends (multiple increases): Screwthread	Internal plane surface and or groove	With gear teeth: Spur gear teeth with auxiliary holes
7		Stepped to both ends (multiple increases): Functional groove and or functional taper (and screw thread)	Stepped to both ends (multiple increases): Functional taper (radial groove) (and screw thread)	Internal spline (polygon)	With gear teeth: Bevel gear teeth
8		Operating thread	Operating thread	Internal spline, external groove and or slot	With gear teeth: Other gear teeth
9		Others	Others	Others	Others

Form code: 13232

Alternative means to Develop Cells/Families:

- They can be company specific
- If so, they are typically hierarchical and list important characteristics of the part/process mix, physical characteristics like size, geometric features, or material, etc.
- Since they are specific they tend to be more accurate in building part families

Alternative means to Develop Cells/Families:

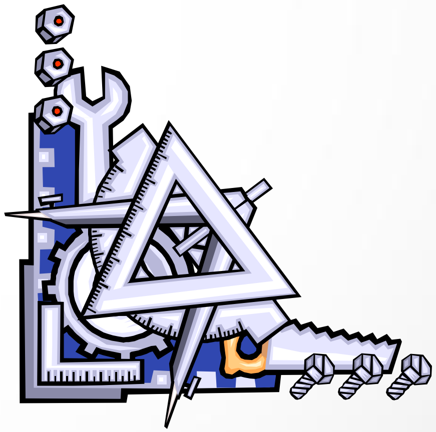
- Using GT Classification and coding systems, parts are coded by experts at the company
- The newly coded part is used to search existing production databases for similarly coded products
- The new part is assigned to the family it most closely matches
- Its routing is thus set and only minor variation needs to be considered
- Using specific digits, a company can target marketing in certain areas of their product mix

Alternative means to Develop Cells/Families:

- In a greenfield shop, managers can develop facility designs (in the form of reasonable cells) by selecting reasonable ‘seed’ parts as suggested by their GT C&C system
- These ‘seeds’ can be used to build routers and, hence appropriate machine clusters
- Using GT C&C systems, process clusters evolve from parts as opposed to clustering evolving by process

Life in the Cell – Working with Family Fixturing Ideas

- Fixturing is a means to speed up part loading and increase accuracy of machine and mfg. processes
- These are tools that:
  - Locate the work for geometric control of various DOF
  - May also provide a means to guide the tooling used to perform the operations (“Jigs”)
  - Before being used these tool must be accurately placed on the machine – often a time consuming task since their placement tolerance must be 10x better than part tolerance!



Life in the Cell – Working with Family Fixturing Ideas

- In CMS, it is often possible to build Family Fixtures
- These are fixtures that can be shared among all the parts in the family (because they are similar geometrically and by mfg. process) thus reducing time to set-up any part in the family
- The Family Fixture is generic and may (likely) require the addition of specific change pieces for different members of the family – but definitely not different fixtures.

Life in the Cell – Working with Family Fixturing Ideas

- Example of Cost Savings:
  - Shop cost is $50/hour
  - Hand setup is 2 minutes/piece (lot is 400 parts)
  - Setup on Fixture is 0.03 min/part
  - Saving of 1.97 min = .033 hr = $1.64/part
  - If machine takes 5 minutes/part, Production rate increases from 8.57 parts/hour to 11.93 parts/hr almost a 40% increase!
  - The company would invest in Fixturing tools if the cost of a fixture applied to a given part over the life of the tooling and part production is less than the $1.64 savings from reduced setup times

Life in the Cell – Working with Family Fixturing Ideas

- Conventional fixturing means a separate fixture for each part made
- Family fixturing means a separate fixture for each family made (but several adaptors for individuals in the family)
- Typically, FFixtures cost more than conventional fixtures – so lets do a cost analysis

Conventional Fixturing

- Facility Tool Costs:

$$C_{tools} = \sum_{i=1}^{P} C_{w_i}$$

P = number of parts needing tooling

where

$$C_{w_i} = C_d + C_m + C_f + C_i + C_h$$

C_d is design cost; C_m is material cost; C_f is fabrication cost; C_i is inventory cost; C_h is handling cost

leads to unit tooling cost/part:

$$C_{u_{tools}} = \frac{\sum_{i=1}^{P} C_{w_i}}{P * n}$$

n = lifetime number of parts to be made (est.)

Family Fixturing:

- Cell Tooling Cost:

$$C_{tools} = C_{FF} + \sum_{i=1}^{Q} C_a(i)$$

Q = number of parts in Family

$$C_a = \textbf{cost of adaptor}$$

$$C_{FF} = C_d + C_m + C_f + C_i + C_h$$

C_d is design cost; C_m is material cost; C_f is fabrication cost; C_i is inventory cost; C_h is handling cost

leads to unit tool cost/part:

$$C_u = \frac{C_{tool}}{Q * n}$$

n = lifetime number of each part in family to be made (est.)

Lets do an Example:

	Conventional	GT Ideas
Main Tool	$500	$1000
# F. Required	1/part	1 for family
Cost Adaptor	NA	$100
No. Adaptors Req'r	NA	.85/part
Typical Order Size	400	400
Typical Batch/lifetime	3batch/yr/3yrs = 3600	3batch/yr/3yrs = 3600

Costs of tooling – a function of the number of parts in a family!

No. Parts	C. Tools	Unit Cost	GT Tools	Unit Cost
1	$500	500/3600 = .139	$1085*	1085/3600 = .301 (.278)
2	$1000	1000/7200 =.139	$1170	1170/7200 = .163 (.153)
3	$1500	1500/10800=.139	$1255	1255/10800 = .116 (.111)
20	$10000	10000/720 [illegible]	$2700	2700/7200 [illegible]

*Note: 1000 + .85*1*100 = 1085 (maybe should be 1000 in a family of 1!

Life in the Cell – Working with Family Fixturing Ideas

- Earlier we found the text author stating that the cost of inventory in a batch is independent of schedule – here we see this may not be the case!
- In a cell, setting up the family fixture is time consuming – but changing between family members is quick and easy – only the time to remove an adaptor and addition of a new one (or not!)
- This leads to the second rung of the factory with a future – SMED – if scheduling is rational in the cells!

Lean Manufacturing is then INTIMATELY tied to CMS and GT

- These methods add efficiency to the production floor
- They improve our quality picture
- They empower employees
- They reduce setup and product change time
- They mean more productivity
- They JUST WORK!

Introduction to Cellular Manufacturing

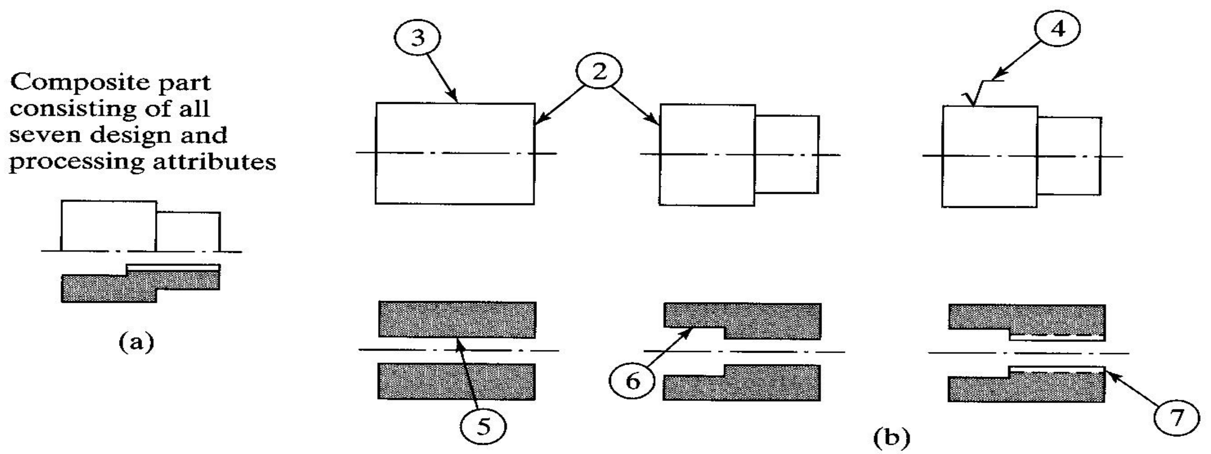
- *Cellular Manufacturing* is an application of group technology in which dissimilar machines or processes have be aggregated into cells,
  each of which is dedicated to the production of a part or product family or a limited group of families.

- Benefits of Cellular Manufacturing

Rank	*Reason for Installing Manufacturing Cells*	*Average Improvement (%)*
1	Reduce throughput time (Manufacturing lead time)	61
2	Reduce work-in-process	48
3	Improve part and/or product quality	28
4	Reduce response time for customer orders	50
5	Reduce move distances	61
6	Increase manufacturing flexibility	
7	Reduce unit costs	16
8	Simplify production planning and control	
9	Facilitate employee involvement	
10	Reduce setup times	44
11	Reduce finished goods inventory	39

Composite Part Concept

- *A Composite Part* for a given family, which includes all of the design and manufacturing attributes of the family.
- In general, an individual part in the family will have some of the features that characterize the family but not all of them. The composite part possesses all of the features



Label	Design Feature	Corresponding Manufacturing Operation
1	External cylinder	Turning
2	Cylinder face	Facing
3	Cylindrical step	Turning
4	Smooth surface	External cylindrical grinding
5	Axial hole	Drilling
6	Counterbore	Counterboring
7	Internal threads	Tapping

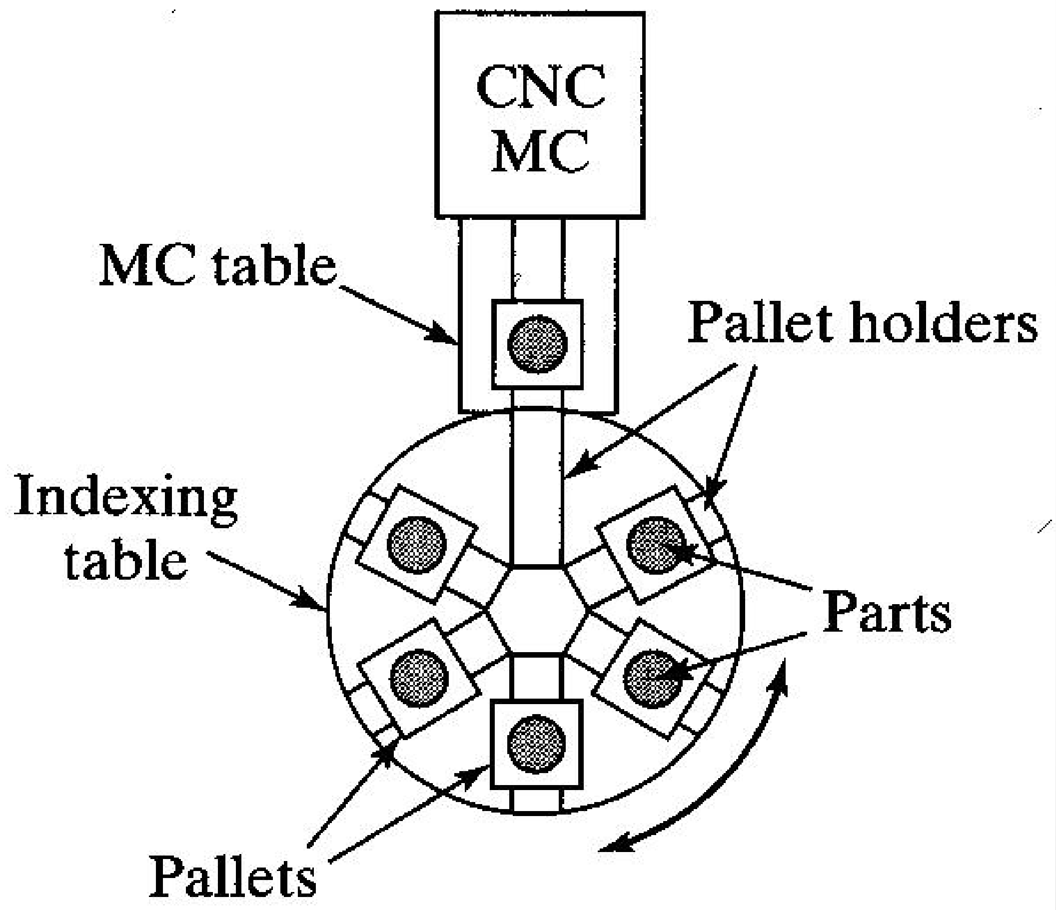
Machine Cell Design

- Design of the machine cell is critical in cellular manufacturing. The cell design determines to a great degree the performance of the cell.

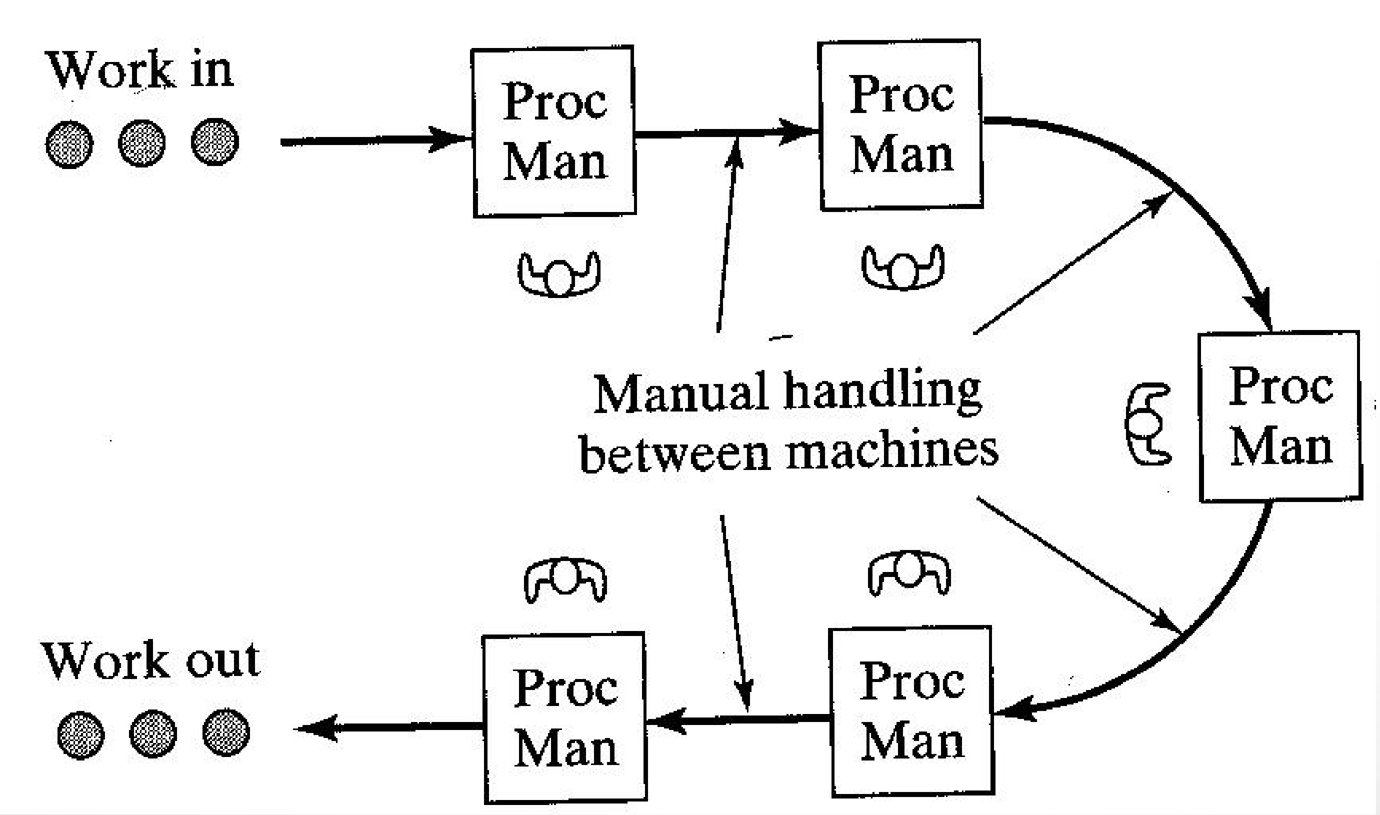
1. Types of machine cells and layouts

- GT manufacturing cells can be classified according to the number of machines and the degree to which the material flow is mechanized between machines.
- Four common GT cell configurations:
  1. Single machine cell (Type I M)
  2. Group machine cell with manual material handling (Type II M generally, Type III M less common)
  3. Group machine cell with semi-integrated handling (Type II M generally, Type III M less common).
  4. Flexible manufacturing cell or flexible manufacturing system (Type II A generally, Type III A less common)

- *Single machine cell* consists of one machine plus supporting fixtures and tooling.
- This type of cell can be applied to workparts whose attributes allow them to be made on one basis type of process, such as turning or milling.



- *Group machine cell with manual handling* is an arrangement of more than one machine used collectively to produce one or more part families.
- There is no provision for mechanized parts movement between the machines in the cell. Instead, the human operators who run the cell perform the material handling function. The cell is often organized into a U-shaped layout.

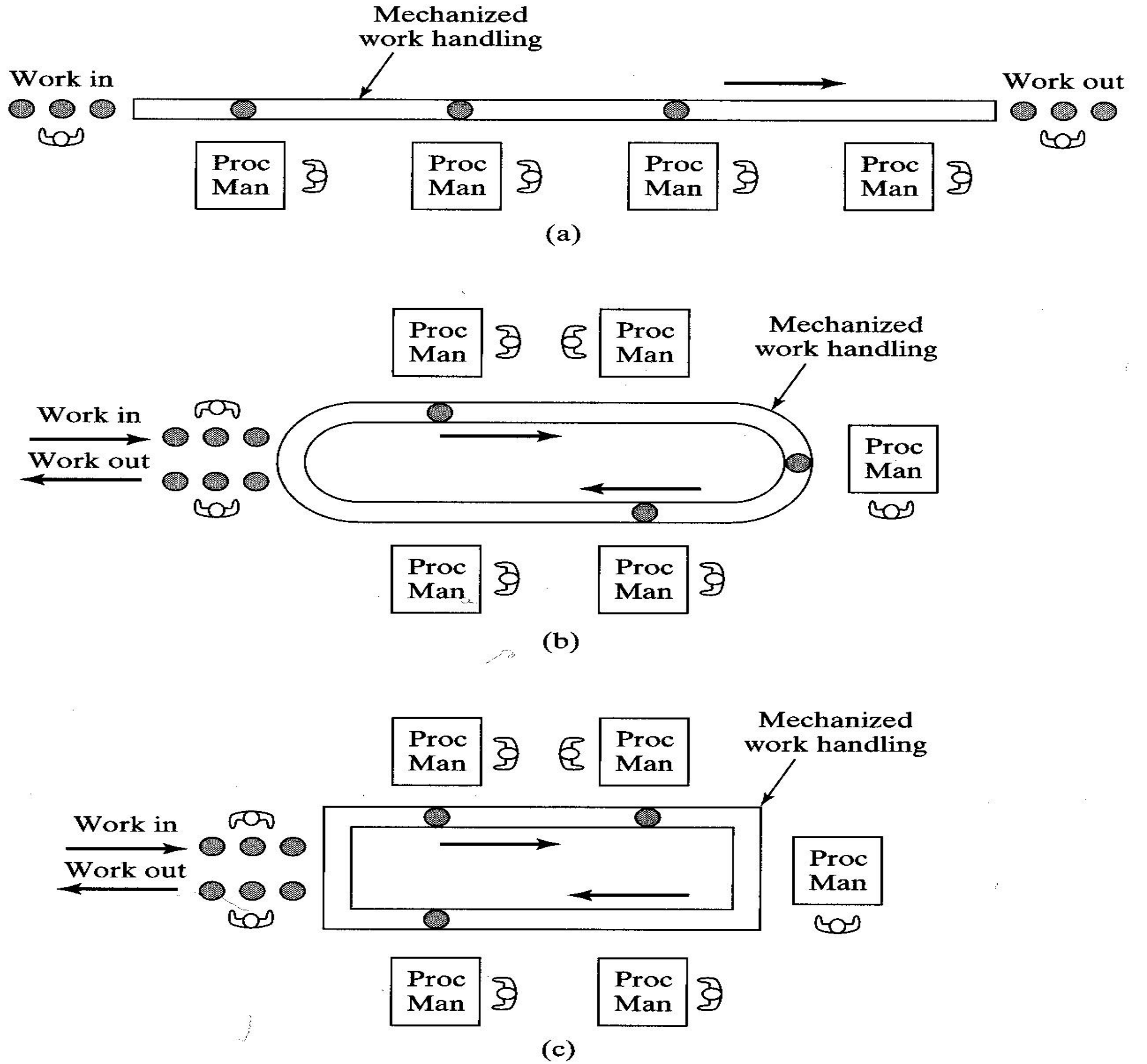


U-shaped Layout

"Proc" = processing
"Man" = manual

Machine Cell Design

- *Group machine cell with semi-integrated handling* uses a mechanized handling system, such as a conveyor, to move parts between machines in the cell.



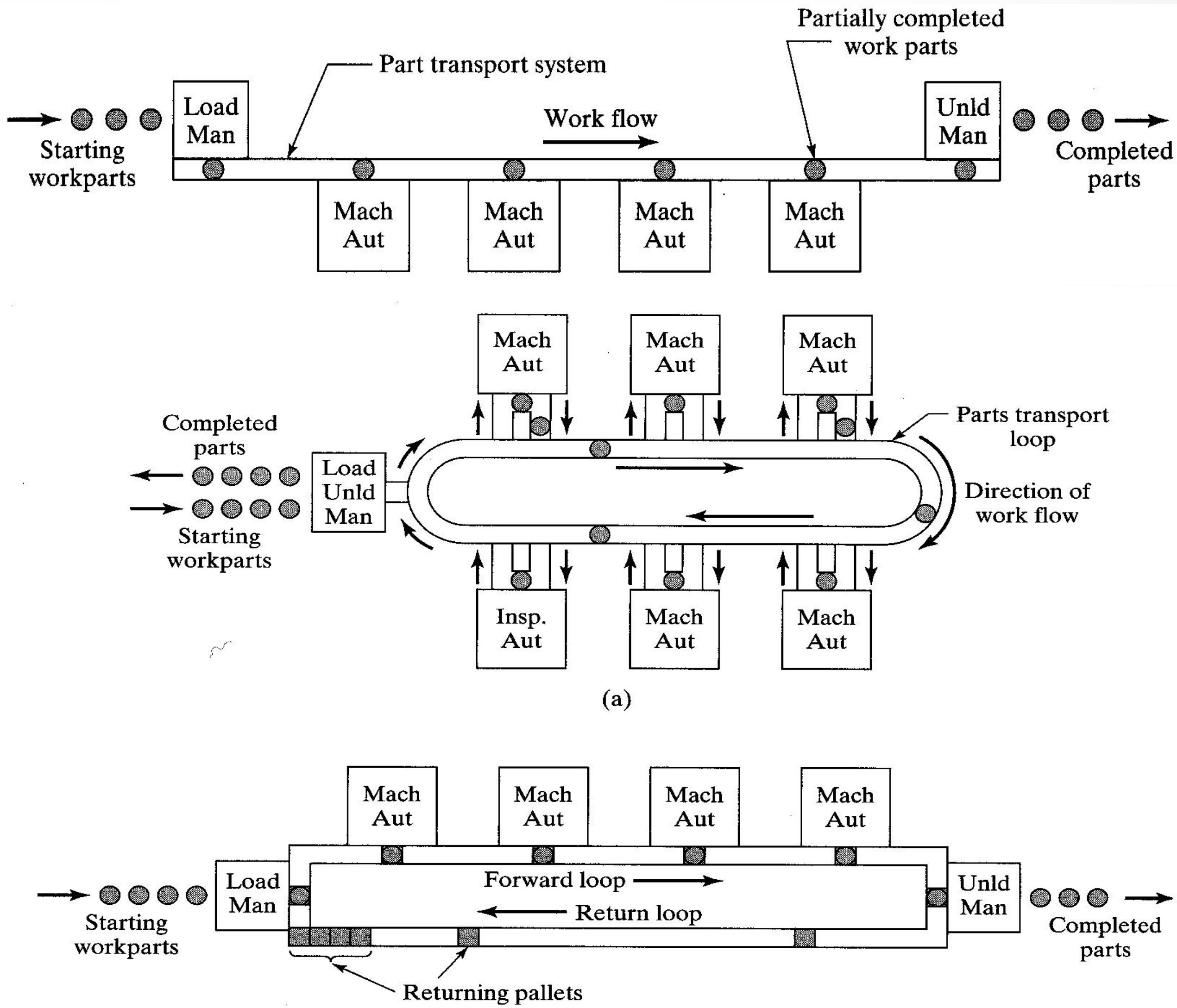
In-line Layout

Loop Layout

Rectangular Layout

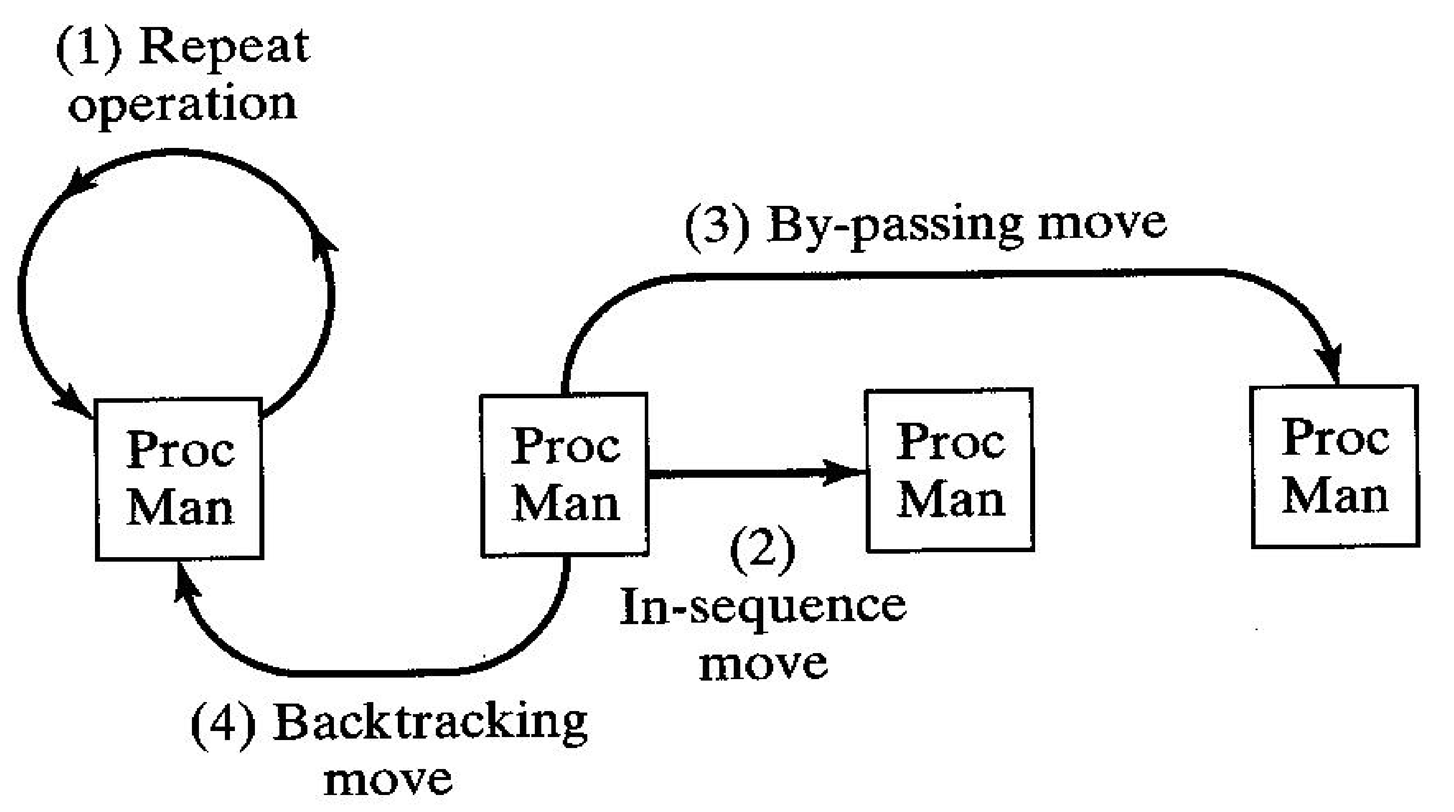
Machine Cell Design

- *Flexible manufacturing system* combines a fully integrated material handling system with automated processing stations.
- The FMS is the most highly automated of the Group Technology machine cells.



2- Types of part movements

- Determining the most appropriate cell layout depends on the routings of parts produced in the cell.
- Four types of part movement can be distinguished in a mixed model part production system.



The forward flow of work is from left to right.

2- Types of part movements

1. *Repeat Operation,* in which a consecutive operation is carried out on the same machine, so that the part does not actually move.

2. *In-sequence move,* in which the part move from the current machine to an immediate neighbor in the forward direction.

3. *By-passing move,* in which the part moves forward from the current machine to another machine that is two or more machines ahead.

4. *Backtracking move,* in which the part moves from the current machine in the backward direction to another machine.

Machine Cell Design

In-sequence moves	In-line layout U-shaped layout
Repeated operations	Multiple stations
By-passing moves	U-shaped layout
Backtracking moves	Loop or rectangular layout

Quantities Analysis in Cellular Manufacturing

- A number of quantities techniques have been developed to deal with problem areas in group technology and cellular manufacturing.

1. Grouping parts and machines into families.
2. Arranging machines in a GT cell.

- The two problem areas have been and still active research areas.

Grouping Parts and Machines by Rank Order Clustering (ROC)

- The Rank Order Clustering (ROC) technique is specifically applicable in production flow analysis. It is an efficient and easy to use algorithm for grouping machines into cells.

- The algorithm, which is based on sorting rows and columns of the machine-part incidence matrix, is given below.
  1. Assign binary weight and calculate a decimal weight for each row using the formula

Decimal weight for row

$$i = \sum_{p=1}^{m} b_{ip} 2^{m-p}$$

Where
m is the number of row and
b is a binary number (0 or 1)

Grouping Parts and Machines by Rank Order Clustering (ROC)

2. Rank the rows from top to bottom in order of decreasing decimal weight values

3. Assign binary weight and calculate a decimal weight for each column using the formula

Decimal weight for column

$$j = \sum_{p=1}^{n} b_{pj} 2^{n-p}$$

Where
n is the number of column and *b* is a binary number (0 or 1)

4. Rank the column from left to right in order of decreasing decimal weight values

5. Continue preceding steps until there is no change in the position of each element in each row and column

Example of Rank Order Clustering Technique

- Apply the rank order clustering technique to the part-machine incidence matrix shown below.

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

Example of Rank Order Clustering Technique

- First iteration (Step 1)

Binary Values	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
					Parts					Decimal	
Machines	A	B	C	D	E	F	G	H	I	Equivalent	Rank
1	1			1				1		290	1
2					1				1	17	7
3			1		1				1	81	5
4		1				1				136	4
5	1							1		258	2
6			1						1	65	6
7		1				1	1			140	3

Example of Rank Order Clustering Technique

- Second iteration (Steps 2 and 3)

Parts

Machines	A	B	C	D	E	F	G	H	I	Binary Values
1	1			1				1		2^6
5	1							1		2^5
7		1				1	1			2^4
4		1				1				2^3
3			1		1				1	2^2
6			1						1	2^1
						1			1	2^0
Decimal Equivalent	96	24	6	64	5	24	16	96	7	
Rank	1	4	8	3	9	5	6	2	7	

Example of Rank Order Clustering Technique

- Solution (Steps 4 and 5)

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

Parts

Arranging Machines in a GT Cell

- After part–machine grouping have been identified by rank order clustering, the next problem is to organize the machines into the most logical arrangement.

- Hollier Method. This method uses the sums of flow “From” and “To” each machine in the cell. The method can be outlined as follows

1. *Develop the From–To chart from part routing data.* The data contained in the chart indicates numbers of part moves between the machines in the cell.
2. *Determine the “From” and “To” sums for each machine.* This is accomplished by summing all of the “From” trips and “To” trips for each machine.

    The “From” sum for a machine is determined by adding the entries in the corresponding row.

    The “To” sum is found by adding the entries in the corresponding column.

Arranging Machines in a GT Cell

3. *Assign machines to the cell based on minimum "From" or "To" sums.* The machine having the smallest sum is selected.
   - If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence.
   - If the minimum value is a "From" sum, then the machine is placed at the end of the sequence.

   Tie breaker
   - If a tie occurs between minimum "To" sums or minimum "From" sums, then the machine with the minimum "From/To" ratio is selected.
   - If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.
   - If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and end of the sequence, respectively
   - *Reformat the From-To chart.* After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the "From" and "To" sums.
4. Repeat steps 3 and 4 until all machines have been assigned

Example of Arranging Machines in a GT Cell

- Suppose that four machines, 1, 2, 3, and 4 have been identified as belonging in a GT machine cell. An analysis of 50 parts processed on these machines has been summarized in the From-To chart presented below. Additional information is that 50 parts enter the machine grouping at machine 3, 20 parts leave after processing at machine 1, and 30 parts leave after machine 4. Determine a logical machine arrangement using Hollier method.

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 of Arranging Machines in a GT Cell

- First iteration

	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	135

Example of Arranging Machines in a GT Cell

- Second iteration with machine 3 removed.

	To:	1	2	4	"From" Sums
From:	1	0	5	25	30
	2	30	0	15	45
	4	10	0	0	10
"To" sums		40	5	40	

Example of Arranging Machines in a GT Cell

- Third iteration with machine 2 removed.

	To:	1	4	"From" Sums
From:	1	0	25	25
	4	10	0	10
"To" sums		10	25	

- The resulting machine sequence 3 š 2 š 1 š 4

Example of Arranging Machines in a GT Cell

- The flow diagram for machine cell in the Example is shown below. Flow of parts into and out of the cells has also been included