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An integrated Approach to the Design of Cellular Manufacturing using group technology

Dr. Mohamed Abdel GawadMostafa
Department of Industrial Engineering,
Zagazig University, Egypt
cadcapp@yahoo.com

Dr. TalalSalehZubairMandourah
Department of Mechanical Engineering,
UQU University, King Saudi Arabia
E-mail: tsmandourah@uqu.edu.sa

***Abstract* – In this paper we develop a mathematical model to capture the complexity of important planning problem inGroupTechnology (GT) Manufacturing Systems, namely, cell formation and part routing selection. Research published so far treats the problem independently in a hierarchical manner. We treat it as equally important decisions and develop a 0–1 integer programming formulation to select part routing and to form cells.The processing time and the machines required to complete processing for seven parts were found out from the routing card of each part. The cell schedule was found using the Shortest Processing Time [SPT] for minimizing makespan. The optimal performance was then established and measured using three different techniques.**

***Keywords* – Cellular Manufacturing, Shortest Processing Time, Makespan**.

I. Introduction

Group technology (GT) is a manufacturing philosophy which capitalizes on similar, recurrent activities. It is a philosophy with broad applicability, potentially affecting all areas of a manufacturing organization. One specific application of GT is cellular manufacturing (CM) cellular manufacturing involves processing collections of similar parts (part families) on dedicated cluster of dissimilar machines or manufacturing processes (cells). The most claimed advantages of CM are better delivery performance , shorter lead time , reduced work-in-process inventories , improved product quality , reduced tooling requirements , reduced material handling etc[10] . Another search [3, 5] had a systematic methodology to construct cellular layouts using GT technique for large size problems. The developed model includes details like machine sequence, production volume and machine revisits for formation of cells.

In this paper we consider a generalized group technology problem of manufacturing a group of parts in which the processing requirements of parts on machines are obtained from the routing cards.

The objective is the formation of cells and the scheduling or determination of the sequence or order in which the part families assigned to a cell should be processed in order to either minimize or maximize some measure of performance [9].

The ROC and SPT methods were used to establish the cell formation. The Cell efficiency was established using three different techniques and a comparative study was then conducted. These methods are namely, Chandrasekhar and Rajaagoplan [4,6], which reveals the goodness fit within a cell and inter-cell movement.[1,2] used shows the low discriminating power of the grouping efficiency between well-structured and ill-structured machines, and it is a direct measure of the effectiveness of utilized an algorithm.SekharaRao [11] regarded as fuzzy uncertainty in part machine matrix. Based on this research, a new similarity coefficient matrix is defined with 0 to one elements. Also, some studies such as [12] made layout decisions concurrently with CMS where demand was stochastic. Many contents are also focused on CMS problem in dynamic situations and stochastic demand in which demand is changed from a period to another period [13, 14].

In practice, costs, demands, processing times [15] set-up times, and the other inputs to classical CMS problems may be highly uncertain so that it can have impact on results sensitively. So, development models for cellular manufacturing problem under uncertainty can be novel area for researchers and belongs to a relatively new class of CMS and scheduling problems that were not researched well in the literature. In this way, random parameters can be either continues or described by discrete scenarios. V. Ghezavati & M. S.Mehrabad [16] designing integrated cellular manufacturing systems with scheduling considering stochastic processing time. Assumed that processing time of parts on machines is stochastic and described by discrete scenarios enhances application of real assumptions in analytical process [17]. This model aims to minimize total expected cost consisting maximum tardiness cost among all parts, cost of subcontracting for exceptional elements and the cost of resource underutilization. An attempt has been made to use Mahalanobis distance, a statistical measure used to classify observations into different groups, for the identification of the part families and machine groups that would result in optimal machine part cell formation.

II. Problem Definition

In this paper we have an example of seven parts which are processed on 8 different machines as in Table (1).

Table 1: Parts and there process

Part Serial	The processes on the part	Processing Time (minutes)	Machine Number
1	Cutting Drilling Welding	5 6 4	1 3 4
2	Cutting	4	1

	Forming Welding Drilling Threading	5 6 5 7	2 4 3 5
3	Cutting Forming	6 7	1 2
4	Cutting Welding	5 5	1 4
5	Shearing Drilling Folding Threading	7 5 5 7	6 3 7 5
6	Shearing Drilling Folding Threading	6 6 7 6	6 3 7 5
7	Shearing Drilling Threading	7 5 7	6 3 5

The objective of applying the cellular manufacturing is to group parts in cells then scheduling the processing of the parts in order to minimize there makespan time .

III. Cell Formation

- The Processing requirements of parts on machines are obtained from the routing.
- This information is commonly represented in a matrix called the part – machine matrix, which is a P × M matrix with 0 or 1 entry.

Table 2: Initial part- machine matrix

		Parts							Decimal equivalent	Rank
		1	2	3	4	5	6	7		
Machines	1		1	1	1				120	(1)
	2			1					48	(4)
	3	1		1		1	1	1	**103**	(3)
	4	1		1	1				104	(2)
	5			1		1	1	1	39	(5)
	6					1	1	1	7	(6)
	7					1	1		6	(7)
Binary weight		2^6	2^5	2^4	2^3	2^2	2^1	2^0		

- The sequence of operation is ignored by this matrix.
- The basic assumption is that the machine type within the group to which the part is assigned has sufficient capacity to process the parts completely.
- Applying the Rank order clustering (ROC) for cell formation.
- Step 1. For row m = 1,2,….., M.

The decimal equivalent C_m by reading the entries as binary words:

i.e. $C_m = \sum_{P=1}^{P} 2^{P-P} \cdot a_{pm} \; (a_{pm} = 0 \text{ or } 1)$ (1)

Then Reorder the Rows in decreasing C_m.
In the Case of a tie, keep the original order.
- Step 2. For column P = 1,2,….., P.
The decimal equivalent r_P by reading the entries as binary words:

i.e. $r_P = \sum_{M=1}^{M} 2^{m-m} \cdot a_{pm} \; (a_{pm} = 0 \text{ or } 1)$ (2)

Then Reorder the Columns in decreasing r_p.
In the Case of a tie, keep the original order.
- Step 3. If the new part, Machine matrix is unchanged, thenstep 4, else go to step 1.

Table 3: Step1, row- Permuted matrix

		Parts							Binary weight
		1	2	3	4	5	6	7	
Machines	1		1	1	1				26
	2			1					25
	3	1		1		1	1	1	24
	4	1		1	1				23
	5			1		1	1	1	22
	6					1	1	1	21
	7					1	1		20
Decimal equivalent		112	124	72	96	23	23	22	
Rank		2	1	4	3	5	6	7	

Table 4: Part family and machine groups(arrangement 1)

		Parts						
		1	2	3	4	5	6	7
Machines	1	1	1	1	1			
	2	1	1	1	0			
	3	1	1	0	0	1	1	1
	4	1	0	0	1			
	5	1				1	1	1
	6					1	1	1
	7					1	1	

The Matrix is as in Table 4 because the Rank is as step1.
- Number of exceptional elements = 4,
Number of voids = 6,
Total = 10

Table 5: Part family and machine groups (arrangement 2)

		Parts						
		1	2	3	4	5	6	7
Machines	1	1	1	1	1			
	2	1	1	1	0			
	3	1	1	0	0	1	1	1
	4	1			1	0	0	0
	5	1				1	1	1
	6					1	1	1
	7					1	1	

- Number of exceptional elements = 6,
Number of voids = 7,
Total = 13

Table 6: Part family and machine groups (arrangement 3)

Machines		Parts						
		1	2	3	4	5	6	7
	1	1	1	1	1			
	2	1	0	0	1			
	3	1	1	1	0			
	4	1	1			1	1	1
	5	1				1	1	1
	6					1	1	1
	7					1	1	0

- Number of exceptional elements = 3,
Number of voids = 4, Total = 7
The part Family an M/C group (arrangement 3) is more suitable to this case. The Part Families are :Group 1- Part 1,2,3,4. Group 2- Part 5, 6, 7.
And the machines group:
Group 1- machines 1, 2, 4. Group 2- machines 3, 5, 6, 7.
So there are two cells:
Cell 1 machine Group 1.
Cell 2 machines Group 2.

IV. Scheduling of Cellular Structure

4-1 Applying Shortest Processing Time Rule (SPT) on the model

Table 7: Machine and processing time for each part

Parts	Machine Sequence	Cell	Processing Times (Min)
Part 1	1, 3, 4	1	5, 6, 4
Part 2	1, 2, 4, 3, 5	1	4, 5, 6, 5, 7
Part 3	1, 2	1	6, 4
Part 4	1, 4	1	5, 5
Part 5	6, 3, 7, 5	2	7, 5, 5, 7
Part 6	6, 3, 7, 5	2	6, 6, 7, 6
Part 7	6, 3, 5	2	7, 5, 7

Table 8: SPT order for jobs and machines

M/C 1	M/C 2	M/C 3	M/C 4	M/C 5	M/C 6	M/C 7
2/4	2/5	2/5	1/4	6/6	6/6	5/5
1/5	3/7	5/5	4/5	2/7	5/7	6/7
4/5		7/5	2/6	5/7	7/7	
3/6		1/6		7/7		
		6/6				

Table 9: Minute–to–minute Schedule: jobs on each machine

Time	M/C 1	M/C 2	M/C 3	M/C 4	M/C 5	M/C 6	M/C 7
1	2	–	–	–	–	6	–
2	2	–	–	–	–	6	–
3	2	–	–	–	–	6	–
4	2	–	–	–	–	6	–
5	1	2	–	–	–	6	–
6	1	2	–	–	–	6	–
7	1	2	6	–	–	5	–
8	1	2	6	–	–	5	–
9	1	2	6	–	–	5	–
10	4	–	6	2	–	5	–
11	4	–	6	2	–	5	–
12	4	–	6	2	–	5	–
13	4	–	1	2	–	5	–
14	4	–	1	2	–	7	6
15	3	–	1	2	–	7	6
16	3	–	1	4	–	7	6
17	3	–	1	4	–	7	6
18	3	–	1	4	–	7	6
19	3	–	2	4	–	7	6
20	3	–	2	4	–	7	6
21		3	2	1	6		–
22		3	2	1	6		–
23		3	2	1	6		–
24		3	5	1	6		–
25		3	5	1	6		–
26		3	5	1	6		–
27		3	5	2	2		–
28			5		2		–
29			7		2		–
30			7		2		–
31			7		2		–
32			7		2		–
33			7		2		5
34			1		5		5
35			1		5		5
36			1		5		5
37			1		5		5
38					5		
39					5		
40					5		
41					7		
42					7		
43					7		
44					7		
45					7		
46					7		
47					7		

The makespan is 47 minute.

Table 10: the machines utilization and Idle times

Machine	M/C Utilization	M/C Idle
M/C 1	42.6 %	57.4 %
M/C 2	25.5 %	74.5 %
M/C 3	57.5 %	42.5 %
M/C 4	31.9 %	68.1 %
M/C 5	57.5 %	42.5 %
M/C 6	42.61 %	51.4 %
M/C 7	25.5 %	74.5 %

4-3 applying shortest processing time (SPT) on the model with Duplication of drilling machine
- There are two cells with duplication of M/C 3
Machine group 1, 2, 3, 4
Machine group 3, 5, 6, 7

Table 11: SPT order for jobs and machines with duplication of drilling machine

M/C 1	M/C 2	M/C 3	M/C 4	M/C 3*	M/C5	M/C6	M/C7
2/4	2/5		1/4	5/5	6/6	6/6	5/5
1/5	3/7	2/5	4/5	7/5	2/7	5/7	6/7
4/5		1/6	2/6	6/5	5/7	7/7	
3/6					7/7		

4-2 A Gantt chart for the model

Fig.1. A Gantt Chart for the model

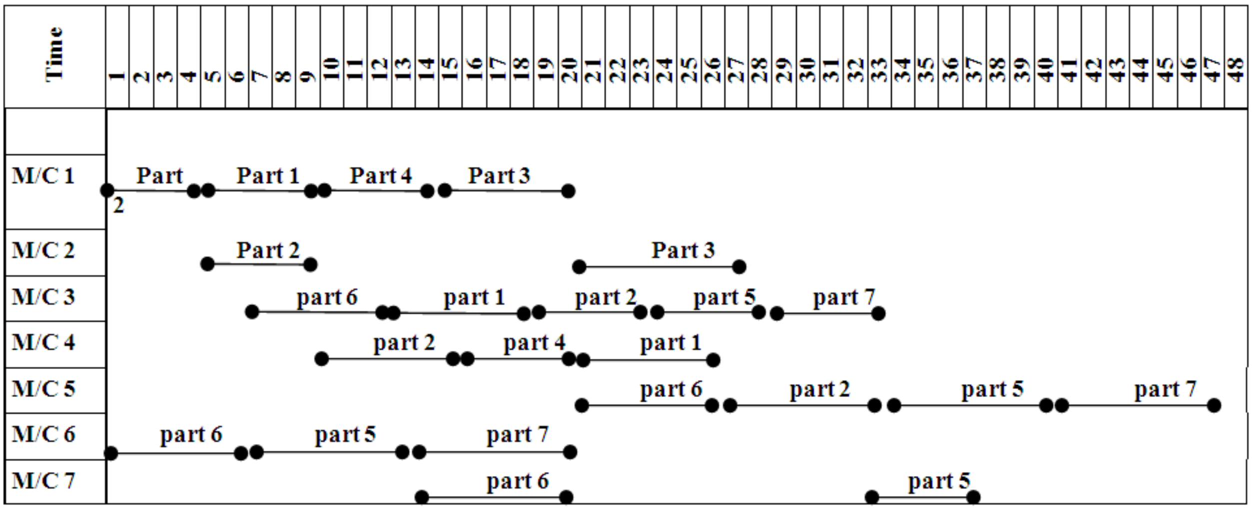
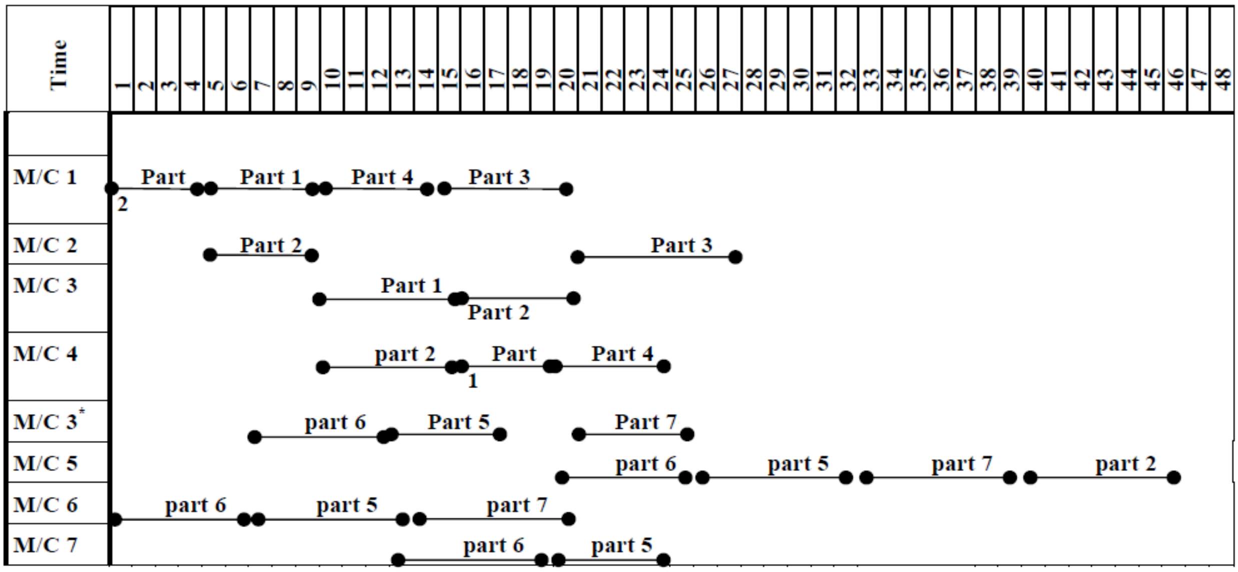


Table 12: minute – to – minute Schedule: jobs on each machine with duplication of drilling machine

Time	M/C 1	M/C 2	M/C 3	M/C 4	M/C3 *	M/C 5	M/C 6	M/C 7
1	2	–	–	–	–	–	6	–
2	2	–	–	–	–	–	6	–
3	2	–	–	–	–	–	6	–
4	2	–	–	–	–	–	6	–
5	1	2	–	–	–	–	6	–
6	1	2	–	–	–	–	6	–
7	1	2	–	–	6	–	5	–
8	1	2	–	–	6	–	5	–
9	1	2	–	–	6	–	5	–
10	4	–	1	2	6	–	5	–
11	4	–	1	2	5	–	5	–
12	4	–	1	2	6	–	5	–
13	4	–	1	2	5	–	5	–
14	4	–	1	2	5	–	7	6
15	3	–	1	2	5	–	7	6
16	3	–	2	1	5	–	7	6
17	3	–	2	1	5	–	7	6
18	3	–	2	1		–	7	6
19	3	–	2	1		–	7	6
20	3	–	2	4		6	7	5
21		3		4	7	6		5
22		3		4	7	6		5
23		3		4	7	6		5
24		3		4	7	6		5
25		3			7	6		
26		3				5		
27		3				5		
28						5		
29						5		
30						5		
31						5		
32						5		
33						5		
34						7		
35						7		
36						7		
37						7		
38						7		
39						7		
40						2		
41						2		
42						2		
43						2		
44						2		
45						2		
46						2		

4-4 A Gantt Chart for the model with duplication of drilling machine

Fig.2. A Gantt Chart for the model with duplication of drilling machine



The makespan = 46 minute

Table 13: the machines utilization and Idle times

Machine	Cell	M/C Utilization	M/C Idle
M/C 1	1	43.5 %	56.5 %
M/C 2	1	26.0 %	74.0 %
M/C 3	1	23.9 %	76.1 %
M/C 4	1	32.6 %	67.4 %
M/C 3	2	34.8 %	65.2 %
M/C 5	2	58.7 %	41.3 %
M/C 6	2	43.5 %	56.5 %
M/C 7	2	26.1 %	73.9 %

Table 14: the machines Utilization and Idle times with duplication of drilling and threading machinesof drilling and threading machines

Machine	Cell	M/C Utilization	M/C Idle
M/C 1	1	53.8 %	46.2 %
M/C 2	1	30.7 %	69.3 %
M/C 3	1	28.2 %	71.8 %
M/C 4	1	38.5 %	61.5 %
M/C 5	1	17.9 %	52.1 %
M/C 3*	2	41.0 %	59.0 %
M/C 5*	2	51.3 %	48.7 %
M/C 6	2	51.3 %	48.7 %
M/C 7	2	30.8 %	69.2 %

4-5 Scheduling with duplication of drilling and threading machines

- There are two cells with duplication of M/C 3 and M/C 5
- Machine group 1, 2, 3, 4, 5
- Machine group 3, 5, 6, 7

The same as sequencing 4-3 except part 2 will be on M/C 5 in the machine group(1, 2, 3, 4, 5) so The makespan will be 39 minute. As in table (12)

V. Performance Measures for Cell Formation

- To compare the quality of solutions obtained by different algorithms on an absolute scale, there is a need to develop performance measure or criteria.
- There are three measures

1- Grouping efficiency ζ.
2- Grouping efficiency τ.
3- Grouping efficiency ζ_g.

- The identification of part families and machine groups which required for the three measures to the two cells are

P = number of parts
M= number of Machines
D = number of 1s in the diagonal blocks
E = number of exceptional elements in the solution
O = number of is the matrix (a_{pm})
V = number of voids in the solution
(Voids refer to the Os inside the diagonal blocks)

5-1 Grouping efficiency ζ

- Proposed by [7, 8].
- The goodness of solution depends on the utilization of machines within a cell and inter-cell movement.

ζWas therefore proposed as a weighted average of the two efficiencies ζ_1 and ζ_2.

$\zeta = w\,\zeta_1 + (1\text{-}w)\,\zeta_2$(3)

Where

$$\zeta_1 = \frac{o-e}{o-e+v}$$

$$\zeta_2 = \frac{MP-o-v}{MP-o-v+e}$$

$$\zeta = (w)\frac{o-e}{o-e+v} + (1\text{-}w)\frac{MP-o-v}{MP-o-v+e} \quad (3\text{-}1)$$

A value of 0.5 is recommended for w

ζ_1 = the ratio of the No. of 1s in the diagonal blocks to the total No. of elements in the blocks (both 0s and 1s)

ζ_2 = the ratio of the No. of 0s in the off diagonal blocks to the total No. of elements in the off-diagonal blocks (both 0s and 1s).

5-2 Groping efficiency τ

- Proposed by Khator, S.K. and Irani, [6]
- Proposed to overcome the low discriminating power of the grouping efficiency between well-structured and ill-structured machines.

$$\tau = \frac{1-\psi}{1+\varphi} = \frac{o-e}{o+v} \quad (4)$$

Where: $\psi = e/o$ and $\phi = v/o$

5-3- Grouper efficiency ζ_g

- Proposed by Chu, C-H. And Tsai. M [5]:
- It's also a direct measure of the effectiveness of an algorithm

$\zeta_g = \zeta_u - \zeta_m \qquad -1 \leq \zeta_g \leq 1$

Where

$\zeta_u = d/(d+v) \qquad 0 \leq \zeta_u \leq 1$

$\zeta_m = 1 - (d/o) \qquad 0 \leq \zeta_m \leq 1$

$\zeta_g = d/(d+v) - 1 - (d/o) \qquad (5)$

Table 15: Calculation of the three performance measures for the two arrangements Table (4) & Table (5).

Performance measure	Arrangement (1)	Arrangement (3)
	M = 7 P = 7 o = 23 e = 4 v = 6 d = 19	M =7 P = 7 o = 23 e = 3 v = 4 d = 19
Grouping efficacy ζ (equation 6-1)	0.38 + 0.4167 = 0.797	0.4167+0.44=0.8567
Grouping efficacy τ (equation 6-2)	0.6551	0.740
Grouping efficacy ζg (equation 6-3)	0.76 – 0.174 = 0.586	0.826-0.174=0.652
The mean efficiency	0.679	0.75

The part family and M/c group (arrangement 3) is more suitable to this case.

VI. Conclusions

In this paper a generalized approach of GT was presented. The cellular manufacturing systems are one specific application of GT. The processing time and the machines required to complete processing the seven parts from the routing card of every part were found, after which the Rank order Clustering (ROC) for the cell formation was applied and which resulted in two cells as given in Table (6) which has total number of exceptional and void elements equal 7 which is the optimum for this case.

The Shortest Processing Time (SPT) for minimizing makespan was applied which resulted in (47 minutes) which is the optimum for this problem. A Gantt chart was used to show the utilization and the idle time of the machines. The drilling machine was then duplicated which resulted in (46 minutes) this was succeeded by to duplicating the threading machines which resulted in a further makespan reduction to (39 minutes) and further improvement in the utilization of the machines .

A performance measure for cell formation in table (13) which gives the mean efficiency for arrangement, which results in shorter lead time, reduced work-in-process inventories, improved product quality, reduce tooling requirements, and reduced material handling.

For Future Research,

We suggest three directions, Development of the model under more and the other stochastic parameters such as costs, processing routes and machine availability. Considering this problem as a multi objective model which considers cell formationdecisions in one objective and scheduling in the other objective. Aggregating proposed model with the other production aspects like layout problem considerations. These remain a critical issue for future study.

References

[1] Arn .EA. (1975) 'Group .Technology: an Integrated Planning and Implementation Concept fo Small and Medium Batch, Production', Springer-verlag, Berlin.

[2] Black, J.T (1983) 'Cellular manufacturing systems reduce setup time, make small lot production economical'. Industrial Engineering November 36-48.

[3] Jai Kannan(2003) 'Splution to large facility layout problems using group technology' International Journal of Production Research, Volume 39, Number 18,4089 - 4101.

[4] Chandrasekaran, M.P. and Rajagopalan, R. (1986) 'An ideal seed non- hierarchical clustering algorithm for cellular manufacturing', International Journal of Production Research, 24(2), 451-64 .

[5] Chu, C-H. And Tsai. M. (1990) 'a comparison of three array based clustering techniques for manufacturing cell formation'. International Journal of Production Research, 28(8), 1417-33.

[6] Khator, S.K. and Irani, S.A. (1987) 'Cell formation in group technology: a new approach'- Computer and Industrial Engineering, 12(2), 131-42.

[7] King, J.R, (1980) 'Machine-component grouping in production How analysis: an approach using rank order clustering algorithm'. International Journal of Production Research, 18(2), 213-32.

[8] Chow, W.S(1992) 'Efficient clustering and knowledge based approach for solving cellular manufacturing problems'. Univ. Manitoba, Canada. Ph .d dissertation.

[9] Jun Wang and C. Roze (1995)'Formation of machine cells and part families in cellular manufacturing'. Computer ind.Engg. Vol. 29, No. 1-4 pp.567-571, 1995

[10] D. Rajamani, N. Singh, and Y.P. Aneja(1990).,'Integrated design of cellular manufacturing systems in the presence of alternative process plans. International journal of production research, 28(8), 1541-1554. Taylor & Francis, ISSN: 0020-7543.

[11] Ravichandran KS, Chandra SekharaRao K (2001) A new approach to fuzzy part family formation in CMS. Int J AdvManufTechnol 18(8):591–597

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[12] Tavakkoli-Moghaddam R, Javadian N, Javadi B, Safaei N (2007) 'Design of a facility layout problem in CMS with stochastic demand'. Appl Math Comput 184(2):721–728
[13] Balakrishnan J, Cheng CH (2005) 'Dynamic C.M. under multiperiod planning horizon'. J ManufTechnol Manage 16(5):516–530
[14] Balakrishnan J, Cheng CH (2007) Multi-period planning and uncertainty issues in C.M.: a review and future directions. Eur J Oper Res 177(1):281–309
[15] Ghezavati VR, Jabal-Ameli MS, Makui A (2009) A new heuristic method for distribution networks considering service level constraint and coverage radius. Expert SystAppl 36(3):5620– 5629 Part.
[16] V. Ghezavati& M. S. Mehrabad (2010)'Designing integrated cellular manufacturing systems with scheduling considering stochastic processing time' Int J AdvManufTechnol (2010) 48:701–717
[17] N. Srinivasa and D. Devika (2011) 'A Novel Approach to Machine-Part Cell Formation Using Mahalanobis Distance'. European Journal of Scientific Research ISSN 1450-216X Vol.62 No.1 (2011), pp. 43-47

AUTHOR'S PROFILE

Dr. Mohamed Abdel GawadMostafa
has permanent work in Zagazig university in Egypt and now working an Associate Professor of Mechanical Engineering, College of Engineering and Islamic Architecture in Umm El Qura University, Mecca , King Saudia Arabia. Ph.D. degree in Industrial engineering. His areas of interest include Computer aided production planning; Computer integrated manufacturing systems, manufacturing modeling, case based reasoning, feature recognition Maintenance, Robotics and control.
E-mail: cadcapp@yahoo.com

Dr. TalalSalehZubairMandourah
is Chairman of the Department of Mechanical Engineering, College of Engineering and Islamic Architecture in Umm El Qura University, Mecca , King Saudia Arabia. Served as the supervisor of the Department of Security and Safety and the supervisor of the management of investment projects at the university. His areas of interest include *Advance Composite Materials, Maintenance*, numerical analysis ,*Safety and Fire Protectio*n, simulation and programming
Email: tsmandourah@uqu.edu.sa