A Time Based Approach for Designing Cellular Manufacturing Systems

Adnan M. Mukattash, Naser M. A. Jaber and Nabeel Mandahawi
Department of Industrial Engineering
The Hashemite University
Zarqa, Jordan

Abstract

In this paper, a time-based approach for designing cellular manufacturing has been developed. Moreover ,the relationship between processing times and optimal or best solution (minimum intercell movements) in cell formation has been discussed and analyzed. The modified approach is consist of two main steps. The first step part assignment is done to the formed cells so as to minimize the number of exceptions and minimize the sum of voids and exceptions. The second step, part assignment is done to the new rearranged time matrixes so as to achieve the highest cumulative processing times inside the cells. The first part assignment may lead to alternative optimal solution. The superiority of the proposed approach is that it based on the comparison between minimum intercell movements and minimum sum of voids and exceptions. For that the highest cumulative processing times inside the cells can be achieved.

Keywords:
Cell Formation, Alternative Optimal Solution , Minimum Exceptions, Intercell Movements, Minimum sum of Voids and Exceptions

1. Introduction

One of the well known methods of increasing the productivity for manufacturing high quality products and improving the flexibility of manufacturing systems is to apply Group Technology (GT) (Miin-Shen and Jenn-Hwai , 2007).Cellular Manufacturing (CM) can be defined as a direct application of group technology in which a manufacturing system is partitioned into subsystems (Ho and Moodie 1996). Machines are grouped into machine cells and parts are grouped into part families based on a binary machine-part incidence matrix. The machine-part incidence matrix is a zero-one matrix, [A] , where element a_{ij}= 1 indicates that part J is processed on machine i. Similarity coefficient approaches represent a well known methodology in grouping machines (Garbie *et al* 2008). The purpose of machine cell formation is to form a set of mutually independent machine cells each capable of fully processing the part families assigned to it (Viswanathan 1996). The cell formation process often includes the identification of exceptional (e) elements (EE). EE create interactions between two independent manufacturing cells. EE can be viewed as parts that require processing on machines on two or more cells. The existence of EE in cell formation solutions is not trivial problem. A void (v) indicates that a machine assigned to a cell is not required for that processing of a part in the cell (Kem and Wei , 1991). Prabhaharan *et al.* in 2005 indicated that most cell formation studies have focused on the independence of clustered cells, and the number of intercell movements is commonly viewed as an indicator of that. Many of the cell formation techniques proposed to date configure cells in such a way to minimize the number of exceptional parts. One of the well known methods for solving cell formation problems based on processing times is developed by S.Angra *et al* (2008).They developed two algorithms based on processing times. The first algorithm can be grouped into three stages:
Stage one: Compute the similarity coefficient
Stage two: Linear cell clustering
Stage three: Assignment phase

Unfortunately, the highest cumulative processing time may not be achieved, by using the first algorithm of S.Angra *et al* (2008), because cell formation is based only on minimum exceptions.
In this paper a time-based approach for designing cellular manufacturing has been developed to overcome the main deficiencies found in the first algorithm of S.Angra *et al* (2008). The main idea of the proposed approach is that, cell

formation is based on minimum exceptions and minimum sum of voids and exceptions. For that the highest cumulative processing times inside the cells can be achieved.

2. Steps of the Time Based Approach

Step One: Use any similarity coefficients from the literature to form cells with minimum exceptions.
Step Two: Repeat step one to form cells with minimum sum of voids and exceptions
Step Three: Assign parts to these cells so as to minimize the number of Exceptions
Step Four: Repeat step three, so as to minimize the sum of voids and exceptions
Step Five: Based on step three and four convert both incident matrixes into time matrix
Step Six: Based on step five assign parts to the cells so as to maximize the cumulative sum of processing times inside the cells.

3. Examples

The following two examples are taken from Surjit *et al* (2008) to illustrate the proposed approach. The first example consists of six parts and five machines as shown below.

Table 1: Part list and machines (example 1)

		PARTS					
		1	2	3	4	5	6
Machines	1	1	1	0	0	0	0
	2	1	1	0	0	0	0
	3	1	1	1	0	1	1
	4	0	0	1	1	1	1
	5	0	0	1	0	1	1

Table 2: Part list and machines with processing times

		PARTS					
		1	2	3	4	5	6
Machines	1	7	4	0	0	0	0
	2	6	7	0	0	0	0
	3	9	8	7	0	5	3
	4	0	0	6	7	5	8
	5	0	0	5	0	3	8

It is found that we have two solutions having the same sum of voids and exceptions (e+v=4), shown below in Table 3 and Table 6.

The first solution is based on minimum exceptions (e=2 , e+v=4) :

Table3: First optimal solution–minimum exceptions =2

		PARTS					
		1	2	3	4	5	6
Machines	1	1	1	0	0	0	0
	2	1	1	0	0	0	0
	3	1	1	1	0	1	1
	4	0	0	1	1	1	1
	5	0	0	1	0	1	1

Table 4: Time-matrix with minimum exceptions

		PARTS					
		1	2	3	4	5	6
Machines	1	7	4	0	0	0	0
	2	6	7	0	0	0	0
	3	9	8	7	0	5	3
	4	0	0	6	7	5	8
	5	0	0	5	0	3	8

Table 5: Time matrix of final clustering (time inside the cells=81)

		PARTS					
		1	2	3	4	5	6
Machines	1	7	4	0	0	0	0
	2	6	7	0	0	0	0
	3	9	8	7	0	5	3
	4	0	0	6	7	5	8
	5	0	0	5	0	3	8

The second solution is based on minimum sum of voids and exceptions (e=3,e+v=4)

Table6: Second optimal solution– (e+v=4)

		PARTS					
		1	2	3	4	5	6
Machines	1	1	1	0	0	0	0
	2	1	1	0	0	0	0
	3	1	1	1	0	1	1
	4	0	0	1	1	1	1
	5	0	0	1	0	1	1

Table 7: Time matrix of final clustering (time inside the cells=83)

		PARTS					
		1	2	3	4	5	6
Machines	1	7	4	0	0	0	0
	2	6	7	0	0	0	0
	3	9	8	1	0	1	1
	4	0	0	6	7	5	8
	5	0	0	5	0	3	8

Compare between the two solutions it is clear that cell formation that based on minimum exceptions may not lead to the highest sum of processing times inside the cells as shown in Table 5. Cell formation in Table 6 is done so as to minimize the sum of voids and exceptions. Based on the distribution in Table 6 we get the highest sum of processing times (83) inside the cells as shown in Table 7. Using S.Angra et al (2008) approach will lead only to the first solution with processing times equal to 81, because their methods did not take into consideration minimum sum of voids and exceptions. The second example consists of fourteen parts and seven machines as shown below.

Table 8: Part list and machines (example 2)

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
M1	0	1	0	0	1	0	0	1	1	0	0	0	0	1
M2	1	0	0	1	1	1	1	0	0	0	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	1	1	1	1	0
M4	0	0	1	0	0	0	1	0	1	0	1	1	0	0
M5	0	1	0	0	0	0	0	1	0	0	0	0	0	1
M6	1	0	0	0	0	1	0	1	0	0	0	0	0	0
M7	1	0	0	1	1	1	0	0	1	1	0	0	0	0

Table 9: Part list and machines with processing times

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
M1	0	6	0	0	3	0	0	9	7	0	0	0	0	8
M2	4	0	0	7	9	8	1	0	0	0	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	3	6	8	7	0
M4	0	0	5	0	0	0	1	0	3	0	6	9	0	0
M5	0	8	0	0	0	0	0	4	0	0	0	0	0	7
M6	5	0	0	0	0	6	0	3	0	0	0	0	0	0
M7	1	0	0	2	2	3	0	0	8	7	0	0	0	0

It is found that we have two solutions having the same sum of exceptions (e=6).

The first solution is based on minimum sum of voids and exceptions (e=6 , e+v=13)

Table10: First optimal solution–minimum e+v=13

	P2	P8	P14	P1	P4	P5	P6	P7	P9	P10	P3	P11	P12	P13
M1	1	1	1	0	0	1	0	0	1	0	0	0	0	0
M5	1	1	1	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	1	1	1	1	1	0	0	0	0	0	0
M6	0	1	0	1	0	0	1	0	0	0	0	0	0	0
M7	0	0	0	1	1	1	1	0	1	1	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	1	0	1	1	1
M4	0	0	0	0	0	0	0	1	1	0	1	1	1	0

Table 11: Time-matrix with minimum inter-cell movements

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
M1	0	6	0	0	3	0	0	9	7	0	0	0	0	8
M5	0	8	0	0	0	0	0	4	0	0	0	0	0	7
M2	4	0	0	7	9	8	1	0	0	0	0	0	0	0
M6	5	0	0	0	0	6	0	3	0	0	0	0	0	0
M7	1	0	0	2	2	3	0	0	8	7	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	3	6	8	7	0
M4	0	0	5	0	0	0	1	0	3	0	6	9	0	0

Table 12: Time matrix of final clustering (time inside the cells=138)

	P2	P8	P14	P1	P4	P5	P6	P7	P9	P10	P3	P11	P12	P13
M1	6	9	8	0	0	3	0	0	7	0	0	0	0	0
M5	8	4	7	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	4	7	9	8	1	0	0	0	0	0	0
M6	0	3	0	5	0	0	6	0	0	0	0	0	0	0
M7	0	0	0	1	2	2	3	0	8	7	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	3	0	6	8	7
M4	0	0	0	0	0	0	0	1	3	0	5	6	9	0

<u>The second solution is based on minimum exceptions (e=6 , e+v=16):</u>

Table13: Second optimal solution–minimum exceptions =6

	P2	P8	P14	P1	P4	P5	P6	P7	P9	P10	P3	P11	P12	P13
M1	1	1	1	0	0	1	0	0	1	0	0	0	0	0
M5	1	1	1	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	1	1	1	1	1	0	0	0	0	0	0
M6	0	1	0	1	0	0	1	0	0	0	0	0	0	0
M7	0	0	0	1	1	1	1	0	1	1	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	1	0	1	1	1
M4	0	0	0	0	0	0	0	1	1	0	1	1	1	0

Table 14: Time matrix of final clustering (time inside the cells=146)

	P2	P8	P14	P1	P4	P5	P6	P7	P9	P10	P3	P11	P12	P13
M1	6	9	8	0	0	3	0	0	7	0	0	0	0	0
M5	8	4	7	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	0	4	7	9	8	1	0	0	0	0	0	0
M6	0	3	0	5	0	0	6	0	0	0	0	0	0	0
M7	0	0	0	1	2	2	3	0	8	7	0	0	0	0
M3	0	0	0	0	0	0	0	0	0	3	0	6	8	7
M4	0	0	0	0	0	0	0	1	3	0	5	6	9	0

Compare between the two solutions ,it is clear that cell formation that based on minimum sum of voids and exceptions may not lead to the highest sum of processing times(138) inside the cells as shown in Table 10 . Cell formation in Table 13 is done so as to minimize the number of exceptions. Based on the distribution in Table 13 we get the highest sum of processing times (146) inside the cells as shown in Table 14.

4. Conclusion

In this paper, a time-based approach for designing cellular manufacturing has been developed. Moreover, the relationship between processing times and optimal or best solution in cell formation has been discussed and analyzed. The time based approached showed the importance of finding all the possible distributions of machines that have the same intercell movements and the same sum of voids and exceptions. Moreover, testing and comparing the same distributions of machines that have the same number of exceptions may not lead to the highest value of processing times. The result of applying our approach shows the superiority in finding the highest cumulative processing times inside the cells since it based on the comparison between the two solutions. The first solution is based on minimum exceptions and the second solution is based on minimum sum of voids and exceptions.

References

Garbie , I.H. , Hamid R.P. and Herman R.L. , Machine cell formation based on a new similarity coefficient , *journal of Industrial and Systems Engineering* , 1(4).p318-344, 2008.

Ho , Y.C. and Moodie , C.L., Solving cell formation problems in a manufacturing environment with flexible processing and routing capabilities. *International Journal of Production Research,* 34(10), p2901-2923, 1996.

Kem,G.M., and Wei, J.C. , The cost of eliminating exceptional elements in group technology cell formation. *International Journal of Production Research,* 29(8), p1535-1547, 1991.

Miin-Shen Yang and Jenn-Hwai Yang , Machine-part cell formation in group technology using a modified ART1 method. *European Journal of Operational Research* , 188 , p 140-152 , 2007.

Prabhaharan, G., Muruganandam, A., Asokan, P. and Girish, B., "Machine cell formation for cellular manufacturing systems using ant colony system approach," *International Journal of Advanced Manufacturing Technology*, 25, p1013-1019 , 2005.

Surjit Angra , Rakesh Sehgal and Z.Samsudeen , Cellular manufacturing-A time –based analysis to the layout problem . *International Journal of Production Economics,*112, p 427- 438, 2008

Viswanathan , S. ,A new approach for solving the P-median problem in group technology. *International Journal of Production Research*, 34(10), p2691-2700 , 1996.