*International Journal of Research in Advent Technology, Special Issue, March 2019*
*E-ISSN: 2321-9637*
*International Conference on Technological Emerging Challenges (ICTEC-2019)*
*Available online at www.ijrat.org*

# Intercell Flow Matrix Based Genetic Algorithm For Cell Formation And Lay Out Design In Cellular Manufacturing

[1]K.Srinivasarao, [2]P.Vijaya Sagar
*[1,2]Asst. Professor*
*Mechanical Department, Tirumala Engineering College*
*Vasu851@gmail.com, Vijayasagar.p@gmail.com*

**Abstract:**Group technology (GT) and a facility layout problem share a common factor to optimize, which is the "Inter cell Flow or Material Handling Flow". Most group technology-based approaches use binary part-machine incidence matrix for cell formation. Impacts of flow volume analysis between machine pairs have not been analyzed in the design of cellular manufacturing systems. A new optimization technique with a "from–to chart" as the primary input, is used to determine the cell formation. A modified grouping efficiency measure is used to determine the efficiency of grouping. Cells formed using the proposed approach show reduced inter cell flows, high grouping efficiencies. A genetic algorithm-based approach is used for machine cell placement. Using the proposed approach show reduced inter cell flows, high grouping efficiencies when compared to earlier approaches. For four case studies are cells are formed and the results are obtained using this techniques are better than or equal to results obtained by earlier authors.
**Keywords**— Cell formation. Layout design. Flow matrix

## 1. INTRODUCTION

Cellular manufacturing system (CMS) is a manufacturing philosophy where similar parts are grouped together on the account of manufacturing design and/or attributes. The basic problem in cellular manufacturing is to group the machines into machine cells and the parts into part families that are named as cell formation. Besides considering the route cards of the parts to develop a generalized and more realistic model for cell formation problem, it is critical to consider other useful production data like operation times and sequences. In this an attempt has been made to tackle the cell formation problem considering operation time of the parts considering total cells load variation is important. Workload among cells will be balanced and flow of materials inside each cell will be smooth by minimizing cell load variation. Consequently, it will minimize work-in-process (WIP), improved performance in terms of throughput, shorter make span, less backtracking and material handling, and minimizing risk of stopping a production line.

In today's competitive environment, manufacturing systems demand high operational efficiency and flexibility while reducing material handling costs. Cellular manufacturing systems (CMS) are recognized for their high operational efficiency, but flexibility is rarely realized due to the delimited cellular structure. Most cell based manufacturing systems use Group Technology concepts to group machines and parts in cells. Solution techniques typically use binary part-machine incidence matrices (PMIM's) for cell formation to achieve high grouping efficiency and reduce intercell flows. A PMIM does not capture the actual volume of product flow between machines and cells.

Cell formation (CF) is a key step in the implementation of group technology – a concept in industrial engineering developed by Mitrofanov (1966) and Burbidge(1961), suggesting that similar things should be processed in a similar way. In the most general setting, the (unconstrained) CF problem can be formulated as follows. Given finite sets of machines and parts that must be processed within a certain time period, the objective is to group machines into manufacturing cells (hence the name of the problem) so that each part is processed mainly within one cell. This objective can be reformulated as minimization of what is usually referred to as the amount of intercell movement – the flow of parts travelling between the cells. This amount can be expressed via the number of parts, their total volume or mass, depending on the particular motivation for CF. For example, if cells are spatially distributed it may become important to reduce transportation costs that depend on the mass or volume rather than on the number of parts. Throughout the decades the problem has gained a lot of attention resulting in hundreds of papers and dozens of approaches that use all the variety of tools ranging from intuitive iterative methods (e.g., McCormick et al., 1972; King, 1980; Wei&Kern, 1989) to neural networks (e.g., Kaparthi&Suresh, 1992; Yang&Yang, 2008), evolutionary algorithms (e.g., Adil&Rajamani, 2000; Filho&Tiberti, 2006) andmixed-integer programming (e.g., Chen &Heragu, 1999; Bhatnagar& Saddikuti,2010); an overview can be found in Selim et al. (1998). Despite all this variety, to the best of our knowledge, there is no tractable approach that explicitly minimizes the intercell movement.

## 2. OBJECTIVE

The objective of this research is to develop a comprehensive cell formation model to integrate GT philosophy with a FLP. The research will address the following specific objectives:

- Develop a mathematical model for forming machine cells which minimize the intercell flows using from–between chart (flow-volume based).
- Develop a new bonding efficiency measure for grouping/cell formation which tries to balance the intercell flow and individual cell density.

## 3. PROPOSED APPROACH

***Machine Cell Formation Using From–Between Charts*:**

The objective is to exploit the relationship between a pair of machines with respect to material flow for forming machine cells using a nonlinear integer programming (NLIP) model and allocate parts to cells using a heuristic which is based on the number of operations and time spent by parts in each cell. The flow between a pair of machines is defined as the sum of flow volume of all products routed between machines based on the product sequence. The flow from machine i to machine j can be calculated as:

$$F_{ij} = \sum_{r=1}^{m} d_r X_{ij} \qquad \forall = i,j \qquad (1)$$

$$f_{ij} = F_{ij} + F_{ji} \qquad \forall = i,j \qquad (2)$$

Values of $X_{ijr}$ are extracted from the production input data as presented in Table 3. For the other case studies, the values are not shown in the data input tables. Table 1 represents the “from–to chart” which is calculated using Eq. 1. A from–to chart can be converted to a from–between chart (Table 2) using Eq. 2. The from–between chart can be represented either as an upper-triangular matrix or as a lower-triangular matrix

.

**Table.1. From-to relationship chart**

| From-to | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | F12 | F13 | F14 |
| 2 | F21 | - | F23 | F24 |
| 3 | F31 | F32 | - | F34 |
| 4 | F41 | F42 | F43 | - |

**Table.2. From-between relationship charts**

| From-between | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | - | F12+F21 | F13+F31 | F14+F41 |
| 2 | - | - | F23+F32 | F24+F42 |
| 3 | - | - | - | F34+F43 |
| 4 | - | - | - | - |

We calculate the total intercell flow for the machine cell configuration. Intercell flow is concerned with only the flow between two machines of different cells. The total intercell flow is the summation of all the flows between machines of different cells. The flow between machines is obtained from the from-between chart. So in step three we calculate the total intercell flow. We also calculate the total flow and intracell flow. Total flow is given as the summation of flows between all the machines. Intracell flow is the flow between the machines of same cell.

Based on the values of total intercell flow, total intracell flow and total flow obtained we now calculate the flow efficiency factor. Flow efficiency factor is used in calculating the grouping efficiency. Flow efficiency factor is defined as the ratio of difference between total flow and intercell flow to the total flow.

$$\text{Flow efficiency factor} = \frac{\text{Total flow} - \text{Intercell flow}}{\text{Total flow}}$$

We now develop the part machine incidence matrix (PMIM). We develop Xir chart where i is the machine and r is part.

We assign $X_{ir}=1$ if part r is processed in the machine i.

= 0 if else.

In this we assign parts to cells. A two-level part assignment heuristic is used to assign the parts to the cells. In the first stage of the part assignment heuristic, a part/cell relationship index is used. The part/cell relationship index (Src) is defined as the ratio of the number of operations performed in machine cell c for part r to the total number of operations required for processing part r.

$$\text{Part/cell relationship index, } S_{rc} = \frac{\sum_{i=1}^{n} X_{ir} X_{ic}}{\sum_{i=1}^{n} X_{ir}} \quad \forall\, r,c$$

Where, Xir is obtained from the production input data presented in Table 4.

The part/cell relationship is calculated for a given part for all cells. The part is assigned to the cell with the highest part/cell relationship index. If there is a tie in the part/cell relationship index then the part/cell processing time relationship index is used to assign the part.

Part/cell processing time relationship index ;

$$Prc = \frac{\sum_{i=1}^{n} T_{ir} X_{ir} X_{ic}}{\sum_{i=1}^{n} T_{ir} X_{ir} X_{ic}} \quad \forall r,c$$

The processing time based part/cell relationship index is defined as the amount of time part r spends in cell c to the total time required in all operations for part r. This approach not only tries to minimize the intercell flow but also tries to reduce the time spent by parts outside the cell in intercellular operations. Each cell should have at least one part assigned to the cell ($L^P=1$) and thus the upper bound on the number of parts assigned to any cell is $U^P=r-q$. Part assignment is repeatedly performed for all cell groupings obtained from the mathematical model. After part assignment, values of $Z_{rc}$ can be obtained from the result.

We now calculate the number of non void blocks by using part machine incidence matrix. The number of non void blocks for a cell is used to calculate the load factor of the cell.

$$\sum_{i=1}^{n} \sum_{r=1}^{m} \mathbf{Z_{rc} X_{ir} X_{ic}}$$

Now calculate the load factor for each cell. The load factor of a cell is defined as the ratio of number of non void blocks to number of machines multiplied by number of parts in that cell.

Load factor of cell = (number of non void blocks in the cell) / (number of machines x number of parts in cell)

We now calculate the average cell load factor. Average load cell load factor for a cell machine configuration is defined as the ratio of sum of load factors of all the cells in the configuration to total number of cells in the configuration.

Average cell load factor = sum of individual cell load factors / number of cells

A new grouping efficiency measure based on the flow volume is used to determine the best cell grouping.

Group efficiency = (□ x flow efficiency factor) + (1-□) x (average load factor).

The grouping efficiency is the weighted sum of flow efficiency factor and the average cell load factor is calculated. The first term is the flow efficiency factor, which is the ratio of the total flow minus the intercellular flow to the sum of total flow. The second term, the average cell load factor, is the summation of the load factor ratios for each cell divided by the total number of cells (q). The load factor for each cell is the ratio of the number of operations in each cell to the number of operations possible in the cells.

Alternatively, the load factor for each cell is the ratio of the number of non-void positions in the PMIM matrix for the cell to the total number of possible positions in the cell. The grouping efficiency index is a modified form of Nair and

Narendran's index that takes into consideration the actual flow of parts between machines and individual cell densities.

To maximize flow efficiency factor, the ideal configuration will be a one cell configuration which make all intercell flow equal to zero. On the other hand, to maximize average cell load factor, the best configuration is to have as many cells as the number of machines. These conflicting factors can be weighted to determine the best number of cells. Thus, a user-defined weight factor χ, ranging from 0–1 is included in the proposed measure for switching weight between the two ratios. Here we use, χ is at 0.5.

## 4. MACHINE CELL FORMATION ANDCALCULATING INTERCELL FLOW AND GROUPING EFFICIENCY.

***Machine Cell Formation For 2 Cells 8 Machines And 20 Parts:***

An 8 M/c's and 20 part case study is used to illustrate the proposed cell formation model. All the three stages are explained and tested for the optimal cell formation and machine cell placement. The results are compared with an existing cell formation approach. This is an existing case study from the Nair and Narendran which does not consider production volume and the processing time. Since the proposed procedure considers both the production factors, the case study data has been modified to include volume and processing time (Table 3).

**Table 3: Production input data of 2 cells 8 machines and 20 parts**

| Parts(r) | Machine Sequence | Processing Time | Product Demand | Xir | Xijr |
|---|---|---|---|---|---|
| **1** | 6-5 | 5-7 | 100 | X6,1=X5,1=1 | X6,5,1=1 |
| **2** | 1-3 | 8-10 | 150 | X1,2=X3,2=1 | X1,3,2=1 |
| **3** | 2-1-7-8-4 | 5-5-8-15-5 | 50 | X2,3=X1,3=X7,3=X8,3=X4,3=1 | X2,1,3=X1,7,3=X7,8,3=X8,4,3=1 |
| **4** | 2-4-7-8 | 8-9-7-10 | 225 | X2,4=X4,4=X7,4=X8,4=1 | X2,4,4=X4,7,4=X7,8,4=1 |
| **5** | 6-5 | 2-5 | 75 | X6,5=X5,5=1 | X6,5,5=1 |
| **6** | 2-4-7-8-5 | 5-4-8-7-10 | 120 | X2,6=X4,6=X7,6=X8,6=X5,6=1 | X2,4,6=X4,7,6=X7,8,6=X8,5,6=1 |
| **7** | 8-4-7-2 | 5-6-8-9 | 160 | X8,7=X4,7=X7,7=X2,7=1 | X8,4,7=X4,7,7=X7,2,7=1 |
| **8** | 1-3 | 5-10 | 45 | X1,8=X3,8=1 | X1,3,8=1 |
| **9** | 1-6-3 | 5-8-6 | 70 | X1,9=X6,9=X3,9=1 | X1,6,9=X6,3,9=1 |
| **10** | 6-4-5 | 12-10-20 | 300 | X6,10=X4,10=X5,10=1 | X6,4,10=X4,5,10=1 |
| **11** | 7-3-1 | 5-8-20 | 150 | X7,11=X3,11=X1,11=1 | X7,3,11=X3,1,11=1 |
| **12** | 5-7-6 | 5-5-16 | 275 | X5,12=X7,12=X6,12=1 | X5,7,12=X7,6,12=1 |
| **13** | 1-3 | 9-15 | 100 | X1,13=X3,13=1 | X1,3,13=1 |
| **14** | 1-2-3 | 7-10-8 | 270 | X1,14=X2,14=X3,14=1 | X1,2,14=X2,3,14=1 |
| **15** | 4-5 | 8-12 | 5000 | X4,15=X5,15=1 | X4,5,15=1 |
| **16** | 1-3 | 1-5 | 300 | X1,16=X3,16=1 | X1,3,16=1 |
| **17** | 3-5-1 | 15-10-5 | 210 | X3,17=X5,17=X1,17=1 | X3,5,17=X5,1,17=1 |
| **18** | 4-2-8-7 | 20-8-6-13 | 100 | X4,18=X2,18=X8,18=X7,18=1 | X4,2,18=X2,8,18=X8,7,18=1 |
| **19** | 1-3 | 2-18 | 125 | X1,19=X3,19=1 | X1,3,19=1 |
| **20** | 4-2-6-7-8 | 5-10-4-10-5 | 75 | X4,20=X2,20=X6,20=X7,20=X8,20=1 | X4,2,20=X2,6,20=X6,7,20=X7,8,20=1 |

**Based on the given data we develop a from to chart. The from-to chart is as follows:**

**Table 4: From to chart of 2 cells 8 machines and 20 parts**

| M/C's | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **1** | - | 270 | 720 | | | 70 | 50 | |
| **2** | 50 | - | 270 | 345 | | 75 | | 100 |
| **3** | 150 | | - | | 210 | | | |
| **4** | | 175 | | - | 5300 | | 505 | |
| **5** | 210 | | | | - | | 275 | |
| **6** | | | 70 | 300 | 175 | - | 75 | |
| **7** | | 160 | 150 | | | | - | 470 |
| **8** | | | | 210 | 120 | | 100 | - |

**Based on the from-to chart we developed we develop the from-between chart which isan upper triangular matrix:**

**Table 5: From-between chart of 2 cells 8 machines and 20 parts**

| M/C's | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **1** | - | 320 | 870 | 0 | 210 | 70 | 50 | 0 |
| **2** | 320 | - | 270 | 520 | 0 | 75 | 160 | 100 |
| **3** | 870 | 270 | - | 0 | 210 | 70 | 150 | 0 |
| **4** | 0 | 520 | 0 | - | 5300 | 300 | 505 | 210 |
| **5** | 210 | 0 | 210 | 5300 | - | 175 | 275 | 120 |
| **6** | 70 | 75 | 70 | 300 | 175 | - | 350 | 0 |
| **7** | 50 | 160 | 150 | 505 | 275 | 350 | - | 570 |
| **8** | 0 | 100 | 0 | 210 | 120 | 0 | 570 | - |

**Table 6: Cell, machine, part assignment table of 2 cells 8 machines and 20 parts**

| Cell | Machines | Parts |
|---|---|---|
| 1 | 2,4,5,6,7,8 | 1,3,4,5,6,7,10,12,15,17,18 |
| 2 | 1,3 | 2,8,9,11,13,14,16,19,20 |

We now calculate the intercell, intracell and total flow for the obtained cell machine Configuration

**Table 7: Internal flow of 2 cells 8 machines and 20 parts**

| FROM-TO M/C'S | FLOW | FROM-TO M/C'S | FLOW |
|---|---|---|---|
| 2-1 | 320 | 6-1 | 70 |
| 2-3 | 270 | 6-3 | 70 |
| 5-3 | 210 | 7-1 | 50 |
| 5-1 | 210 | 7-3 | 150 |

**Grouping Efficiency Calculation (2Cells):**

Total intercell flow =1350
Total flow =10880
Total intracell flow =9530

We now calculate the flow efficiency factor for the cell machine configuration.

$$\text{Flow efficiency factor} = \frac{\text{Total flow- Intercell flow}}{\text{Total flow}}$$

$$= \frac{10880-1350}{10880}$$

$$= 0.875.$$

We now develop the part machine incidence matrix (PMIM). We obtain this matrix $X_{ir}$ by assigning 1 if the part "r" flows through machine "i" else 0 otherwise.

**Table 8: PMIM table of 2 cells 8 machines and 20 parts**

| Xir | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **2** | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| **3** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **4** | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| **5** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| **6** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **7** | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| **8** | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |

No of parts in cell1 =11
No of parts in cell 2 =9
**For cell1** No of parts X no of machines = 11 X 6=66
**For cell2** No of parts X no of machines =9 X 2=18

We now obtain the non void blocks from the part machine incidence matrix. The non Void blocks are given below.

Total number of non void blocks for cell 1=38
Total number of non void blocks for cell2=18
Load factor for cell 1 = 38/66 =0.575
Load factor for cell 2 = 18/18 =1
Average cell load factor = Sum of load factors for all cells/ no of cells
= (0.575+1)/2
=0.787.
Group efficiency =(□×flow efficiency factor)+(1-□)×(average load factor)
=(0.5×0.876)+(0.5)×(0.787)
=0.832.

Therefore the grouping efficiency of the cell machine configuration with 2 cells,8 machines and 20 parts is 83.2%

Proposed cell configuration (8MC’sX 20 parts) for 3 cells.

**Table 9: Results of 2 cells 8 machines and 20 parts**

| **Cell** | **machine** | **Part assignment** | **Grouping efficiency** | **Intercell flow** |
|---|---|---|---|---|
| 1 | 2,4,5,6,7,8 | 1,3,4,5,6,7,10,12,15,17,18 | 83.2 | 1350 |
| 2 | 1,3 | 2,8,9,11,13,14,16,19,20 | | |

## 5. RESULTS AND DISCUSSIONS

Results obtained by Krishna Kumar Krishnan:

**Case1:** For 8MC’sX 20 parts problem described chapter. The obtained from the present work is same as Krishna Kumar Krishnan.

**Table10: Cell configuration for (8MC’sX 20 parts)**

| **Cell** | **machine** | **Part assignment** | **Grouping efficiency** | **Intercell flow** |
|---|---|---|---|---|
| 1 | 2,4,5,6,7,8 | 1,3,4,5,6,7,10,12,15,17,18 | 83.2% | 1350 |
| 2 | 1,3 | 2,8,9,11,13,14,16,19,20 | | |

**Case2:** For 13 M/C’s X 13 parts analysis .The results obtained from the proposed work is getting better values than the results obtained by earlier authors

**Table11: Cell configuration for (13 M/c’s x 13 parts)**

| Cell | Machine Assignment | Part Assignment | Grouping Efficiency | Intercell Flow |
|---|---|---|---|---|
| 1 | 1,2,4,6,7 | 2,4,8,10,13 | 82% | 2950 |
| 2 | 5,8,9,12,13 | 1,3,7,11 | | |
| 3 | 3,10,11 | 5,6,9,12 | | |

**Case3:** For 15m/c’s X 25 parts problem. The results obtained from proposed work comparatively equal in inter cell flow value but better grouping efficiency than the results obtained by earlier authors

**Table12: Cell Configuration for (15M/c’sx25 Parts)**

| **Cells** | Machine | Parts Assignment | Grouping | Intercell Flow |
|---|---|---|---|---|

| | Assignment | | Efficiency | |
|---|---|---|---|---|
| **1** | 2,3,6,11 | 2,4,8,13,19,25 | 83.7% | 5700 |
| **2** | 1,5,9,12 | 1,5,16,20,23 | | |
| **3** | 8,14,15 | 3,6,7,14,17,21,24 | | |
| **4** | 4,7,10,13 | 9,11,12,15,18,22 | | |

**Case4:** For 16 M/c's X 43 parts problem the results obtained from proposed work comparatively better inter cell flow but equal grouping efficiency than the results obtained by earlier authors

**Table13: Cell configuration for (16 M/C's X 43 Parts)**

| Cells | Machine Assignment | Parts Assignment | Grouping Efficiency | Intercell Flow |
|---|---|---|---|---|
| 1 | 1,2,9,16 | 2,4,10,18,28,32,37,38,40,42 | 67.9% | 33866 |
| 2 | 7,13 | 25 | | |
| 3 | 4,5,6,8,10,15 | 1,3,5,8,9,12,13,14,15,16,19,21,23,26,29,31,33,39,41,43,6,24,11,20,22 | | |
| 4 | 3,14 | 7,17,35,36,34 | | |
| 5 | 11,12 | 27,30 | | |

**Comparison of results:**

For validation of proposed approach the results obtained by the proposed approach, the four case studies solved are compared with krishna kumar Krishnan et al and mahdavi et al compared to results are tabulated in table .

**Table14: Comparative Results**

| Case study | Intercell Flow | | | | | Grouping Efficiency | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| No Of M/c'sxparts | Proposed | Krishna Kumar krishnan | Mahdavi | Wu's | Won& Lee | Proposed | Krishna Kumar krishnan | Mahdavi | Wu's | Won& Lee |
| 8m/c's x 20 parts | 1350 | 1350 | | | | 83.2 | 83.2 | 76.49 | | |
| 13m/c's x13 parts | 1810 | 2950 | | 2090 | | 83.78 | 82.0 | 81.08 | 83.0 | |
| 15m/c's x25 parts | 5700 | 5700 | | | | 84.01 | 83.7 | 83.72 | | |
| 16m/c's x43 parts | 28448 | 33866 | | | 34256 | 67.5 | 67.9 | 53.24 | | 58.0 |

**Results obtained by other author's et al.**

- For (8M/C's X 20 parts)problem results obtained from the proposed work getting better grouping efficiency by Mahdavi et al.[12]
- For (13M/C's X 13 parts)problem results obtained from the proposed work getting better grouping efficiency by Mahdavi et al.[12]
- For (15M/C's X 25 parts)problem results obtained from the proposed work getting better grouping efficiency by Mahdavi et al.[12]
- For (16M/C's X 43 parts)problem results obtained from the proposed work getting better grouping efficiency by Mahdavi et al.[12]
- For (13M/C's X 13 parts**)** problem results obtained from the proposed work in both inter cell flow and grouping efficiency is getting better values than the obtained by Wu's[.
- For (16 M/C's X43 parts) analysis the results obtained from the proposed work in both intercell flow and grouping

efficiency is getting better values than the results obtained by Won and Lee.

The developed optimization approach for the integrated solution of cell formation performs same values or better than krishna kumar Krishnan et al and mahdavi et al.

## 6. CONCLUSION

In this project the detailed development of an integrated methodology for cell formation and facility layout based on the flow between machines. The grouping procedure is implemented using an optimization approach.

The efficiency of the grouping procedure is determined using a modified grouping efficiency expression. This technique is better than the techniques developed by earlier authors.

## REFERENCES

[1] Chandrasekharan MP, Rajagopalan R (1989) Groupability: an analysis of the properties of binary data matrices for group technology. Int J Prod Res 27:1035–1105

[2] Li D, Sun X (2006) Nonlinear Integer Programming. Springer Science and Business Media, LLC. International Series in Operations Research & Management Science, pp.315–319

[3] Garbie IH, Parsaei HR, LeepHR (2005) Introducing new parts into existing cellular manufacturing systems based on a novel similarity coefficient.Int J Prod Res 43(5):10071037

[4] .Groover M, Zimmers E (1984) CAD/CAM: computer-aided design and manufacturing.Prentice Hall, USA

[5] Gupta T, Seiffodini H (1990) Production data based similarity coefficient for machine component grouping decisions in the design of a cellular manufacturing system. Int JProd Res 28 (7):1247–1269

[6] Harhalakis G, Nagi R, Proth JM (1990) An efficient heuristic in manufacturing cell formation for group technology applications. Int J Prod Res 28(1):185–198

[7] .Heragu SS, Kakuturi SR (1997) An interactive program for machine grouping and layout. In:Parsaei HR, Kolli S, Hanley TR (eds) Manufacturing decision support systems,Chapman and Hall Engineering Series on Manufacturing Systems. Chapman and Hall,London, UK, pp 180–203

[8] Islam KMS, Sarker BR (2000) A similarity coefficient measure and machine parts grouping in cellular manufacturing systems. IntJ Prod Res 38(3):699–720

[9] .Krishnan KK, Jithavech I, Liao H (2009) Mitigation of risk in facility layout design for single and multi-period problems, Int J Prod Res, Vol.1, No.30, pp

[10] 10.Kumar CS, Chandrasekharan MP (1990) Grouping efficiency: a quantitative criterion for goodness of block diagonal forms of binary matrices in group technology. Int J Prod Res 28:233–243

[11] Logendran R (1991) Impact of sequence of operations and layout of cells in cellular manufacturing. Int J Prod Res 29 (2):375–390

[12] Mahdavi I, Shirazi B, Paydar MM (2008) A flow matrix-based heuristic algorithm for cell formation and layout design in cellular manufacturing system. Int J AdvManufTechnol39:943–953

[13] Miltenburg J, Zhang W (1991) A comparative evaluation of nine well-known algorithms for solving the cell formation in Group Technology. J OperManag 10(1):44–72

[14] Montreuil B, Venkatadri U, Rardin RL (1999) Fractal layout organization for job shop environments. Int J Prod Res 37(3):501– 521

[15] Nair GJ, Narendran TT (1998) CASE: a clustering algorithm for cell formation with sequence data. Int J Prod Res 36 (1):157–179

[16] Ng SM (1993) Worst-case analysis of an algorithm for cellular manufacturing. Eur J Res 69(3):384–398

[17] . Offodile OF (1991) Application of similarity methods to parts coding and classification analysis in group technology. JMS 10 (6):442–448

[18] Rajasekharan M, Peters BA, Yang T (1998) A genetic algorithm for facility layout design in flexible manufacturing systems. Int J Prod Res 36(1):95–110

[19] Tompkins JA, White JA (1996) Facilities planning. Wiley, New York, NY 20. Won Y, Lee KC (2001) Group technology cell formation considering operation sequences and production volumes. Int J Prod Res 39(13):2755–2768

[20] Wu N (1998) A concurrent approach to cell formation and assignment of identical machines in group technology. Int J Prod Res 36:2099–2114

[21] Yasuda K, Hu L, Yin Y (2005) A grouping genetic algorithm for the multi-objective cell formation problem. IntJ Prod Res 43 S(4):829–853.