# Simultaneous Part Family Identification & Grouping of Machines in Cellular Manufacturing using Correlation Analysis Approach

**M. Prabhu**

Research Scholar

Karpagam University.

Coimbatore,Tamilnadu

India

**Dr. G. Karuppusami**

Dean

Sri Eshwar College of Engineering

Coimbatore,Tamilnadu

India

**Abstract**: In group techonology, to solve cell formation problem in a multivariate approach based on correlation analysis to find optimal part and machine grouping and also in which exceptional machines and parts are considered. The proposed approach is carried out in three phases. In the first phase, the correlation matrix is used as similarity coefficient matrix. In the second phase, Principal Component Analysis (PCA) is applied to find the eigenvalues and eigen vectors on the correlation similarity matrix. A scatter plot analysis as a cluster analysis is applied to make simultaneously machine groups and part families while maximizing correlation between elements. In the third stage, an algorithm is improved to assign exceptional machines and exceptional parts using respectively angle measure and Euclidian distance Extending the proposed approach to identify the role of part family in lean manufacturing system, and role of design conformance in lean manufacturing system, role of GT Management & automated factor in lean manufacturing systems direction are our interesting research perspective.

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The outline of the paper is as follows: Section1 describes the introduction, Section 2 describes literature review, Section 3 explains exiting methods and problems in manufacturing CF problem which using similarity coefficients approach, CF problem with exceptional machines and parts and performance criteria. Then the proposed approach is presented in Section 4 by giving presentation for each proposed methodology phase. Lastly, conclusion is drawn in Section 5.



**Keywords: Group technology, Cellular manufacturing, Lean manufacturing, PCA**

## 1.0 Introduction:

### 1.1Group Technology:

Group Technology (GT) has considerable effects on important dimensions of lean production such as production wastes, set up time, quality and inventory management.The relationship between the two subjects has not sufficiently been addressed in the literature. In this paper, a conceptual model has been proposed for enhancing productivity through the application of Group Technology (GT) in lean production systems. The model includes dimensions of GT and its relationship with lean production goals.

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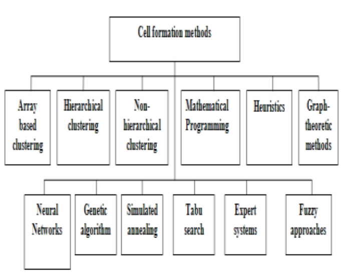
- Group technology is a philosophy that utilizes similarities in product design & production process.
- Cellular manufacturing,play an important role in Group Technology used for various appplications.
- Important problem in design CM system is Cell formation (CF).
- CF constructs part families with similar process requirements and machines into machine cells to optimize production process.

**1.2 Cellular Manufacturing (CM):** It has been emerged as a strong approach for improving operations in batch and job shop environments. In cellular manufacturing, Group Technology is used to form part families based on similar processing requirements. Parts and machines are then grouped together based on sequential or Simultaneous techniques. This approach results in cells where machines are located in relative proximity; Based on processing requirements rather than similar functional aspects, decision-making and accountability are more locally focused, often resulting in quality and productivity improvements. In general, Cell Formation Techniques can be broadly classified.

- Descriptive Procedures,
- Cluster Analysis,
- Graph Partitioning,
- Artificial Intelligence,
- Mathematical Programming




## 2.0 Literature Review:

CF research in the literature can be divided into three categories, according to the formation logic used (indicated by J. Geonwook, 1998; Wang, 2003 and others):
(a) Grouping part families (e. g. in Kusiak, 1987) or machine cells only (b) Forming part families and then machine cells (e. g. in Choobineh, 1988; Adenso-Diaz et al,2005),
(c) Forming part families and machine cells simultaneously (e. g. in Adil et al, 1993).

In general, descriptive procedures can be classified into three major classes. The first class, which is referred to as Part Families' Identification (PFI), begins the cell formation process by identifying the families of parts first and then allocates machines to the families. The second class, which is referred to as Machine Groups Identification (MGI). The third class of the descriptive procedures, which is referred to as Part Families/Machine Grouping (PF/MG), identifies the Part Families and machine groups simultaneously. PFI methods can be sub classified as those based on informal systems (e.g., rules of thumb, visual examination or other criteria) and those based on formal coding and classification systems. The role of group technology (GT) codes in the context of cellular manufacturing is primarily as an aid in identifying the part families to which production cells should be dedicated. Further analysis is required before a family of parts to be manufactured in a cell, and the machines, which will comprise that cell, can be specified. MGI procedures consider the CF problem as a two stage process where in the first stage of their analysis and machines are grouped based on information available in part routings and then in the second stage, parts are allocated to machine groups. When a CF approach attempts to group parts into part families and machines into machine groups simultaneously, then such an approach can be classified as PF/MG.

Burbidge [1971] proposed one of the earliest PF/MG descriptive approaches for the CF problem which is referred to as Production Flow Analysis (PFA). PFA is a technique, which analyses the information given in route cards to form cells. A manual method for CF called "Nuclear Synthesis" is proposed where manufacturing cells are created around "key machines". E1-Essawy [1972] proposed a method called Component Flow Analysis (CFA) at about the same time. In some respects, the methodology of CFA does differ from that of Burbidge's PFA procedure since the latter first partitions the problem, whereas the former does not. Detailed description of PCA method can be found in the relevant literature Labordere, (1977); Rummel, (1988); Harkat, (2003) Gnanadesikan, (1997).

## 3.0 Existing System:

In industry, it is not easy to make all parts and machines into stand alone cells, and therefore a separate shop to look after such kind of special operations becomes mandatory. There are firms having some operations outside the cells for different products and spare parts whose changing demand patterns tend to disturb the cell routine works. It has also been pointed out that as the range of parts becomes wider, with parts in different stages of their lifecycles, it is preferable for the manufacturing system to be configured in a hybrid manner. In order to improve grouping efficiency of the cells, inter-cell movement, logistics handling and so on. There have been numerous methods available in the literature including modern methods like Simulated Annealing (SA), Genetic Algorithms (GA), Tabu Search (TS), Greedy approaches, Variable-Depth search, Hill climbing procedures, and Ant Colony Optimization (ACO), which can be used to solve such objective functions theoretically. In this paper a potential of correlation techniques for manufacturing cell formation has be considered.

**Disadvantages:**

- Inflexibility determining number of cells.
- Limited industrial application.
- Unavailability of software program support.

The proposed system overcomes the above draw backs.

## 4.0 Proposed Methodology:

Part family grouping procedures are used for identifying groups of parts that are similar to one another. Some approaches focus attention on grouping machine cells only but these procedures often assume that part families have already been formed. Part-machine grouping procedures are for identifying part families and machine groups sequentially or simultaneously.

The proposed methodology falls into the third category (i.e., forming part families and machines groups simultaneously). This approach consists in solving machine-part grouping problem, identifying exceptional machines and parts and solving CF problem mode by assigning theses exceptional elements. To this effect, an original technique is used in proposing a new definition of similarity coefficient matrix and the Principal Component Analysis (PCA) as a cluster method. These techniques allow the identification of part families and machine groups simultaneously and the identification of exceptional machines and exceptional parts.

**Description of the proposed approach:**

The proposed approach consists in three phases to find machine and part grouping using PCA as mentioned below

### 4.1. Similarity coefficient matrix

The first phase consists in building a similarity matrix. The initial machine-part incidence matrix consider is a binary matrix in which rows are parts and columns stand for machines.Note that this proposed definition looks like the transpose of classical incidence matrix.

Where $a_{j}^{i}$ =1 if machine j is required to process part i and $a_{j}^{i}$ =0 otherwise. $M_J$ is a binary row vector from the matrix A $M_j^A$ $[a_{j}^{1}, a_{j}^{2} \ldots\ldots a_{j}^{p}]$

To make the initial matrix (A) more sufficiently meaningful and significant, its standardization is needed.. In this article, the general standardization of the initial data set is used. It is expressed by:

$M_j^B = M_j^A - Ej/\sum j$

The proposed similarity coefficient is based on the simple correlation matrix of the incidence matrix. The correlation matrix S is defined as follows:

Correlation matrix Sj: $S_j = 1/P\ B'B$

Sij is m x m matrix whose elements are given.

Table 1: Incidence Matrix

| | m1 | m2 | m3 | m4 |
|---|---|---|---|---|
| p1 | 1 | 1 | 0 | 1 |
| p2 | 0 | 1 | 1 | 0 |
| p3 | 1 | 0 | 0 | 1 |
| p4 | 0 | 0 | 0 | 1 |
| p5 | 0 | 0 | 0 | 1 |
| p6 | 0 | 1 | 1 | 1 |

c

### 4.2 Cluster analysis for correlation

In the second phase of the proposed approach, the machine groups and part families are identified by factor and graphical analysis. The objective is to find machine groups, part families and parts common machines using some classification scheme given by using Factor analysis representation of the data.

Factor analysis is a powerful multivariate analysis tool used to analyze the interrelationships among a large number of variables to reduce them into a smaller set of independent variables called factors. Factor analysis was developed in 1904 by Spearman in a study of human ability using Mathematical models. Since then, most of the applications of factor analysis have been used in the psychological field. Recently, its applications have been expanded to other fields such as Mineralogy, Economics, Agriculture and Engineering. Factor analysis requires having data in form of Correlations, and uses different methods for extracting a small number of factors from a sample correlation matrix. These methods include: common factor analysis, principal component analysis, image factor analysis, and canonical factor analysis.

PCA is the most widely used method. It is an investigation of the data that is largely widespread among users in many areas of science and industry. It is one of the most common methods used by data analysts to provide a condensed description. PCA is a dimension reduction technique which attempts to model the total variance of the original data set, via new uncorrelated variables called principal components. PCA consists in determining a small number of principal components that recover as much variability in the data as possible. These components are linear combinations of the original variables and account for the total variance of the original data. Thus, the study of principal components can be considered in statistical terms the usual developments of eigenvalues and eigenvectors for positive semi-definite matrices. Statistical terms usual development of Eigen value and Eigen vector of the semi definite matrices.

Eigen vectors as (F1,F2…….Fn)

$PC = \lambda 1 + \lambda 2 / \sum \lambda m$

In this application of ACP, the objective is clustering machines in group and parts in families. A binary decision is applied at each machine and part. Two principal components are enough to analyze correlation between elements (machines and parts).

Like example, let us consider the dataset contains two machines and five parts. The data can be represented by a two dimensional scatter plot where each machine is represented by a line from the origin and each part is represented by a dot located at its weight in each line (machine).

Graphical clustering analysis is based on an angle distance measure. An angle distance measure θ, or normalized scalar product is used. It defined as:

$$\vartheta = arccos\left(\sum xiyi \Big/ \sum x_i^2 \sum y_i^2\right)$$

Where, xi and yi are the coordinates of Pi in the scatter plot.

Table2: The correlation matrix of machines corresponding to the incidence matrix

| | m1 | m2 | m3 | m4 |
|---|---|---|---|---|
| m1 | 1 | | | |
| m2 | 0 | 1 | | |
| m3 | -0.5 | 0.707107 | 1 | |
| m4 | 0.316228 | -0.44721 | 0.63246 | 1 |

c

**4.3 Assign algorithm for exceptional elements**

The objective of the third phase is to assign exceptional parts and exceptional machines to preliminary cells.

In most CF problem, there are usually exceptional parts and exceptional machines. For each type of exceptional element, an assign algorithm is proposed.

**1. For the assignment of exceptional machines:**

This iteration continues until all exceptional machines are assigned to form machine groups. Let em is the number of exceptional machines.

For k = 1 to em do

Step 1: Compute angle measure for each machine (different to Mk and not an exceptional machines) θ = min (θ -θ , 2π- θ -θ ) Where θi is the angle measure between Mi and the first principal component, θi.

Step 2: Since the objective is to group machines with minimum angle distance, Machine Mi which has the smallest angle distance with Mk, and is assigned to the machine groups Mi ,End.

**2. For the assignment of exceptional parts:**

An exceptional part can be viewed as a part that requires processing on machines in two or more cells. Let ep is the number of exceptional part. The clustering algorithm for exceptional part is shown below:

This iteration continues until all exceptional parts are assigned to form part families.

For k = 1 to ep do

Step 1: Compute Euclidean distance for each part with the exceptional part Pk

Where xi and yi are the coordinates of Pi in the scatter plot (two principal components).

Step 2: Since the objective is to group parts with minimum distance, part Pi which has the smallest distance, is assigned to the part families Pi,End.

These recent researches demonstrated to be better in comparative studies. Therefore, it could be said that the proposed approach is valid. It is more flexible and able to get correlation information between each machine and part.

Table3: Tabular presentation of the Eigen analysis of the Correlation Matrix of Machines

**Principal Component Results for:**

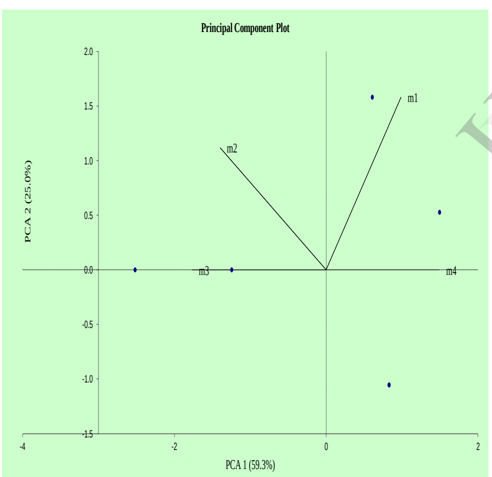
**Principal components calculated from the correlation matrix**

**Components extracted with eigenvalues > 1**

**Explained Variance (Eigen values)**

| Value | PC 1 | PC 2 | PC 3 | PC 4 |
|---|---|---|---|---|
| Eigen value | 2.374 | 1.000 | 0.500 | 0.126 |
| % of Var. | 59.340 | 25.000 | 12.500 | 3.160 |
| Cum. % | 59.340 | 84.340 | 96.840 | 100.000 |

Fig 2: Scatter Plot for machines and parts cell formation




### 4.4 Computational Result:

Performance of proposed approach has been evaluated using multiple performance criteria for test different size (m x p) cell formation problem, comparison study is made optimization of result.

Advantages of Proposed System:

- More flexible
- Able to get correlation information between manufacturing process.
- Validity to solve CF problem.
- Perform very well in terms of number of well known criteria.
- Flexibility in allow the user either to identify the required number of cell in advance.
- Facilitate industrial application

## 5.0 Final conclusion

In this paper, a new approach is presented for part-family and machine-cell formation. The main aim of this article is to formulate a correlation analysis model to generate optimal machine cells and part families in GT problems. The correlation matrix for similarity machine and part is used as similarity coefficient matrix. Principal Components Analysis (PCA) method is applied to find the optimal machine and part elements. Exceptional machines and parts are easily assigned to cells using cluster algorithm.

The proposed method is a logical and systematic approach to the design of cellular manufacturing systems which makes it easily portable into practice, is that it uses PCA, which are available in many commercial software packages and it can be performed on most statistical packages including SAS (1985), SPAD (1995), SPSS (1999), S-PLUS, XLSTAT, and others.

Computational experiences show that the proposed approach does not require long computing times and gives the same solution than the other proposed approaches in recent literature. Although the present approach focuses on the compactness of formation solution only, it can readily accommodate other manufacturing information such as production volume, sequence and alternative routings.

Extending the proposed approach to this direction is our interesting research perspective.

**5.1 Further Study:**

- Aim to identify relation between group technology and lean production to increase power of operation to decrease overall production
- Consider effect of GT on important dimension of lean production waste, set up time quality of inventory management.
- Try to propose a conceptual model for enhance productivity through application proposed GT in lean production system.

A study on statistical analysis on companies explains the role of part family in lean manufacturing system, design conformance in lean manufacturing system and also GT management, automated factor in lean manufacturing systems..

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