# A MULTI CRITERIA APPROACH TO DESIGNING THE CELLULAR MANUFACTURING SYSTEM

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## ABSTRACT

Cellular manufacturing system design problems such as design framework, manufacturing cells layout and layout evaluation. The research objective is developing the framework to designing manufacturing cells with considering the organization and management aspects in shopfloor. In this research have compared the existing layout with proposed layout which applied the multi criteria approach. The proposed method is combining Analytical Hierarchy Process (AHP), Clustering and heuristic approach. The result has show that grouping with Single Linkage Clustering (SLC) to be selected as manufacturing cells. The comparison of clustering weight is 0,567, 0,245 and 0,188 for SLC, Complete Linkage Clustering (CLC) and Average Linkage Clustering (ALC), respectively. This result shows that generating layout by using grouping result from SLC. The evaluation result shows that types of manufacturing cells better than process layout which used the existing system.

**Keywords:** cellular manufacturing system, AHP, clustering, heuristik

## 1. INTRODUCTION

Cellular manufacturing system (CMS) have been viewed as a system from conventional manufacturing to integrated manufacturing system and the factory of the future. CMS offers the potential to move from inflexible, repetitive batch, mass production to more flexible small-lot production at reasonable costs. Cell formation design is obviously a key issue in CMS design. In general, for a production facility with a given number of machines and part mix to be processed in the facility, there are three specific decisions in cell formation design, that are the number of manufacturing cells to be established, the machines constituting each cell and the parts assigned to each cell.

Many manufacturing firms which hither to satisfied their customers while operating job shop production systems have recently had to rethink because of the superiority of group technology. Implementation CMS have some benefit that essential for competitive advantages of organization (Silviera, 1999). For medium size industry based on manufacturing, design of CMS will give the contribution to reduce source of the waste as setup times, material handling effort and WIP inventory.

The basic idea of CMS is to process a collection of similar parts (part families) on a dedicated cluster of dissimilar machines (machine groups). Forming and formation the machine groups needs an approach that comprehensive because it should consider aspects of processes and layout problems. Design of CMS has some problems that are the framework of design, laying out the manufacturing cells and evaluating the layouts. The main objective of the research is introducing a suggested the framework to design the manufacturing cells under shop floor organization aspects. The aspects will be compared using multi criteria approach for evaluating existing layout and manufacturing cells proposed. The certain questions must be researched and

answered are: (1) How the framework of designing manufacturing cells? (2) What layout objectives should be included? And, (3) How the evaluating the layout proposed using multi criteria approach?

Many cell formation methods in the literature do not consider real-life organization factors in production facility. Due to the complexity of the cell formation problems, the research is developed to include some aspects in the organization of production facility. Alternative selection in layout problem is usually included multi attribute with the result that needed multi attribute analysis. In this research, existing and proposed layouts have been compared using the multi criteria decision making approach.

## 2. LITERATURE REVIEW

CMS can be defined as an application of group technology (GT) which involves grouping machines or processes on the basis of parts or the part families they process (Groover, 2000). Cell Formation (CF) is the first phase of CM, and it deals with the identification of the part family or families and associated machine groups that constitute each cell. The complete review of techniques dedicated to CF has been presented in a paper by Mansouri, et. al. (1998). The second phase of CM consists of the system design of each of the previously identified cells. Typical decisions in this phase include equipment layout; selection/design of tooling and fixtures; design of material handling equipment; determination of the number of machine operators; assignment of the operators to the machines or workstations; specification of the capacity of buffers between workstations; and the formulation of machine-setup policy in a workstation (Singh, 1996). Other factors that have to do with operation and control of the cell are to be included in this phase since they have proven to be an important influence on the performance of a manufacturing system. It is not possible to delineate a strict sequence of decisions to be made in connection with cell design. One can, however, say that structure oriented decision and to proceed procedure-oriented ones. Furthermore, the system structure and the procedures can be changed as experience is derived during the operation of the cell system over time. Within the group of structural decisions, identification of part families and machine groups takes on particular significance, since most subsequent decisions depend on these choices.

The facility layout problem deals with finding the most effective physical arrangement of facilities, personnel, and any resources required to facilitate the production of goods or services. It has attracted the attention of many researchers because of its practical utility and interdisciplinary importance. Historically, two basic approaches have most commonly been used to generate desirable layouts: a qualitative one and a quantitative one. These approaches are usually used one at a time when solving a facility layout problem. With qualitative approaches, layout designer provide subjective evaluation of desired closeness between departments. Then, overall subjective closeness ratings between various departments are maximized. These subjective closeness ratings can be used: absolutely necessary, essentially important, important, ordinary, unimportant and undesirable, to indicate the respective degrees of necessity that to given departments be located close together. Quantitative approaches involve primarily the minimization of material handling costs between various departments.

Many researchers have questioned the appropriateness of selecting a single criterion objective to solve the facility layout problems because qualitative and quantitative approaches each have advantages and disadvantages. The major limitations on quantitative approaches are that they consider only relationship that can be quantified and to not consider any qualitative

factors. The shortcoming of qualitative approaches is their strong assumption that all qualitative factors can be aggregated into one criterion. In real life, the facility layout problem must consider quantitative and qualitative criteria and this falls into the category of the multi objective facility layout problem. Many models and solution approaches have been developed to deal with the problem of manufacturing cell design/formation since 1970s. The design of manufacturing cells with respect to multiple criteria has been an attractive research topic since 1990. This section presents a review on the main features of the models developed in this field. Baker, R.P and Maropoulos, P.G. (2000) develop a framework to design the manufacturing cell with 0-1 matrix incidence as input to forming machine groups. In this paper, they have been consider only minimizing exceptional elements. Although they consider cells capability however alternatives of grouping is not generate. The main limitation in this research is not considered other performance measure such as the grouping efficacy function, cells independence and others. Chan and Abhary. (1996) has been too where alternatives is generated with using two different techniques. Machine grouping is formed with single objective. Nevertheless, the approach to select layout alternatives using multi criteria decision making. They focused for automated cellular manufacturing system. Onwubolu (1998) have been develop an approach to cluster machines and components with objective minimizing the voids of block diagonal. In spite of, they give proposing grouping performance measure to evaluate the clustering results.

In the same way, Hadiguna and Setiawan (2003) and also Singgih and Hadiguna (2003) have been applied hierarchical clustering in three techniques to forming machine cells. They develop a framework to laying out cells in two stages that are first, machine-component grouping and second, to laying out intra cell and inter cells. The approach advantage is applying AHP to evaluating the existing layout compared with proposed cells. The limitation is not considered some criteria that is usually used to cluster machine and component in form 0-1 matrix incidence. Akturk and Balkose (1996), by means of a coding scheme which includes both. Design and manufacturing attributes of parts, calculate the similarity and dissimilarity of parts and makes use of them in a six objective model. The objectives are concerned with minimizing: the dissimilarities based on the operation sequences, the total machine investment cost, the sum of the workload variability in each cell, the work load variability of different cells, and the number of skipping which refers to the number of machines a part skips in its operation sequence. Method suggested is a multi objective cluster analysis heuristic to deal with these objectives simultaneously. AHP is employed to determine priority of the objectives in order to unify them. The research is concerned to group part and machines without arrangement of shop floor.

## 3. RESEARCH METHOD

The proposed method is comprised of four sequential approaches: selection of grouping method, grouping analysis, generating layout, and evaluation. The selection of grouping method is necessary to determine how grouping the machines and the components should be worked. In this approach, method used to select the grouping method is AHP which developed by Saaty (2002). AHP need some criteria to build the hierarchy structure. In this concerning, Silveira (1999) was introduce the criteria as based on selecting the grouping method. The criteria are parts/machines variety, grouping subjects, cost, time analysis and personal decision. Whereas types of grouping are visual analysis, codification systems, coefficients of similarity, clustering algorithms and mathematical programming. The result in this approach is grouping method selected that used to group the machines.

Second approach is grouping analysis where is the grouping method selected used to cluster the machines based on the binary incidence matrix that obtained from the production processes. The result of group expected can generate some alternative the group. The group can as manufacturing cell alternatives. The alternative should select with some considerations such as number of cells, similarity level, purity, independent cells and efficacy. The above considerations can use because a result of grouping based on binary matrix is not usually needed the layout criteria. By using binary matrix then value of the considerations can be analyzed. Furthermore, the alternatives are analyzed by using AHP to select the best grouping.

The generating layout is third approach. To generate layout be needed intensity travel and space data. Objectives of layout are minimizing total travel distance and inter cells travel distance. The total travel distance of component in the layout problems is generally used whereas inter cells distance be needed to show degree of independent cell. According to Suresh (1996), the creation of mutually independent machine cells with no inter cell movement is one of the important goals of cell design. However, it may not always be economical or practical to achieve mutually independent cells. In practice, therefore, some parts need to be processed in more than one cell. In this approach could be applied AHP when is not find a layout with minimization both of objectives. Layout method used to generate the layout is opt algorithm with aided computer software was developed by Heragu (1997).

Finally, evaluation approach as fourth approach is used to compare existing layout with proposed layout based manufacturing cell. Principle of evaluation approach is multi objective layout problem by using AHP. Qualitative factors is be generated by interview with personal who is understand the layout performance. The evaluation is initially identification some relevant factors. The relevant factors are choice by using natural cut off approach that used by Suryadi and Prasetyo (2002) and Suryadi and Dewi (2002). Whereas quantitative factors considered are total distance and space usage. Both of factors can obtain from computer software. From to chart matrix be needed as input the computer software. Generally, research method is developed above may be view as a framework to design a manufacturing cell for small manufacturing company. The framework can illustrated a diagram in Figure 1.

## 4. RESULTS

The purpose of this section is to illustrate the use of the proposed framework with a real application. Some background of the problem is presented first, then each of the steps of the approaches is illustrated along with the data used throughout the study, and finally, results are discussed and conclusions are drawn.

### 4.1. Product Reference

This research was conducted on a local company to evaluate the existing layout. The company (hereafter referred to as "Company X") manufactures agriculture equipment/machinery in a make-to-order fashion. This time, the company has been manufactured some product variety around ten types. The layout evaluation must be initially choice the product reference. Product reference selected based on some considerations such as continuous produced, most processes type and profitability. Based on these considerations was obtained two product reference that is hydrotiller and hammer mill. After product reference have been selected so production processes need to identification.

The process for manufacturing products reference has five of unit operations sequence: cutting, machining, assembling, inspection, and marking. The research is concentrated for process type like as cutting and machining.

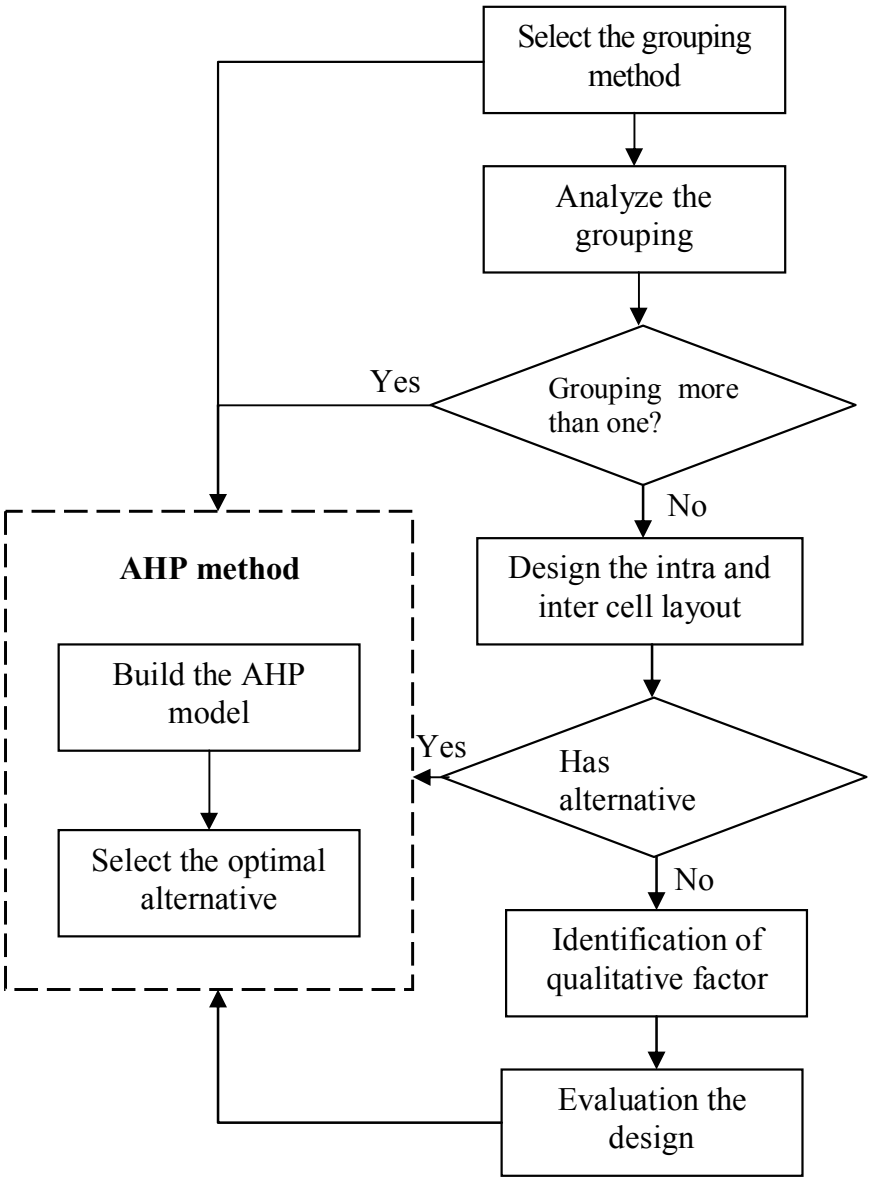


**Figure 1. The Proposed Framework**

### 4.2. Selection of Grouping Method

First approach is selection process of grouping method. Method used is AHP with pairwise comparison by researcher. Judgment necessity conducted by researcher because the grouping method unless understanding by decision maker in the company. Hierarchy structure is illustrated in Figure 2 below. Method selected is who have most priority weight. The similarity clustering is to be selected as shown in Figure 3. The reasoning of this method selected because easier from point of view: parts and machines variety, grouping subjects, time analysis required and personal decision included.

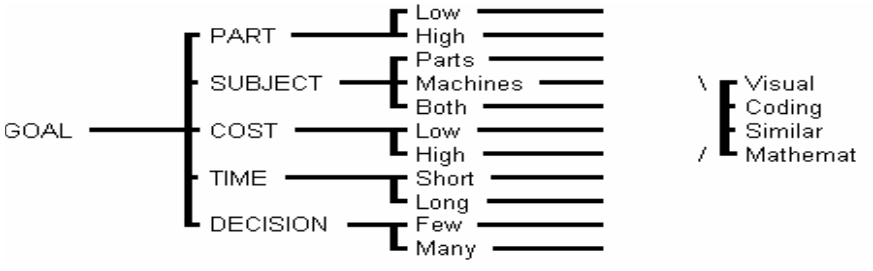


**Figure 2. Hierarchy Structure of Method Selection**

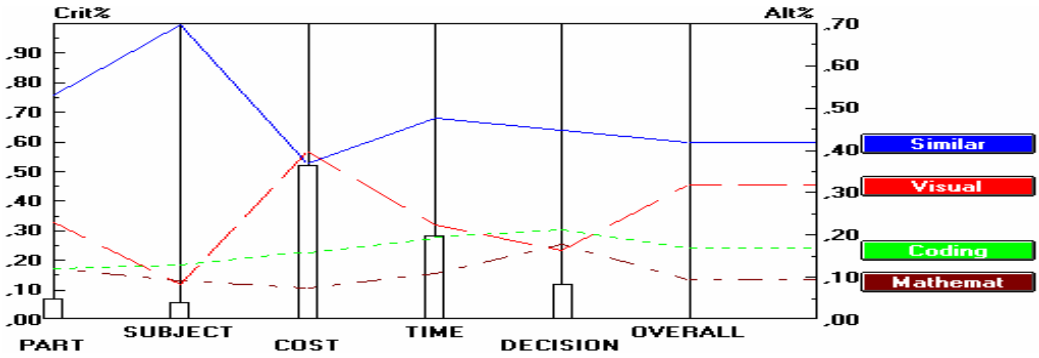


**Figure 3. AHP Result**

### 4.3. Machines and Components Grouping

Furthermore, machine grouping is conducted by similarity analysis where popularity techniques used is hierarchical clustering. Hierarchical clustering has three way: single linkage clustering, complete linkage clustering and average linkage clustering. These ways is applied to group machines with the result that three grouping alternatives. Type of machines as member a cell can drawn in Table 1 and also the number of cells from three ways of clustering respectively.

**Table 1. Types of Machine in Cells**

| No. | SLC | CLC | ALC |
|---|---|---|---|
| 1. | M3 – M8 – M7 | M4 – M5 | M2 |
| 2. | M1 – M10 – M12 | M1 – M12 – M6 – M7 | M9 |
| 3. | M4 – M5 – M9 | M3 – M8 – M10 – M11 | M3 – M8 – M7 |
| 4. | M2 – M6 – M7 – M11 | M2 – M9 | M4 – M5 |
| 5. | – | – | M1 – M12 |
| 6. | – | – | M6 – M7 – M10 – M11 |

Machines cells and part families that formed must be analyzed to know the performance respectively. Result the analysis can see in Table 2 below. We can see that severally cells have advantages and limitations.

**Table 2. Summary of Alternatives Analysis**

| Criteria | Alternatives | | |
|---|---|---|---|
| | SLC | CLC | ALC |
| No of Cells | 4 | 6 | 4 |
| Similarity Level | 64,52 | 53,95 | 55,42 |
| Purity | 1 | 0,75 | 0,666 |
| Independent | 55 | 51 | 43 |
| Efficacy | 0,70517 | 0,70513 | 0,60426 |

Because of these different, we have to apply AHP method to select machine cells. Analysis result shows that SLC selected as proposed manufacturing cell. Weight comparison of these cells is illustrated in Table 3 for SLC, CLC and ALC, respectively. This result shows that generating layout only use grouping from SLC.

**Table 3. Weight Comparison of SLC, CLC and ALC**

| Criteria | Alternatives | | | Criteria Priority Weight |
|---|---|---|---|---|
| | SLC | CLC | ALC | |
| No of Cells | 0,429 | 0,143 | 0,429 | 0,165 |
| Similarity Level | 0,637 | 0,105 | 0,258 | 0,055 |
| Purity | 0,637 | 0,258 | 0,105 | 0,141 |
| Independent | 0,637 | 0,258 | 0,105 | 0,552 |
| Efficacy | 0,429 | 0,429 | 0,143 | 0,086 |
| Priority Weight | 0,567 | 0,245 | 0,188 | |

### 4.4. Generating of Layout Alternatives

Generating layout is designed in two stages that is intra cells layout and inter cells layout. Designing processes need work cell space and from to travel data. Work cell space is planned under consideration of allowance and space allocation for material, operator and material handling equipment. Above result is an optimal solution that obtained with software aided which used opt algorithm. Because of result have optimal then it is not necessary to apply AHP method. Summary of layout result can see in Table 4 below.

**Table 4. Summary of Layout**

| Objectives | Cell 1 | Cell 2 | Cell 3 | Cell 4 | *Inter cell* | Total |
|---|---|---|---|---|---|---|
| Distance (m) | 97,084 | 21,032 | 56,479 | 88,582 | 320,740 | 583,917 |
| Space ($m^2$) | 87,5 | 99,88 | 40,0302 | 81,279 | – | 308,6892 |

### 4.5. Evaluation

Evaluation constitutes final approach that used to comparison of proposed layout and existing layout. First step is identify attributes which is continued with selection of relevant attributes by using natural cut off. Attribute is generated by literature study which drawn aspects of organization especially in shop floor. Analysis of relevant attribute shows that easy to supervise and team working which obtain total score 3.

Selection of attribute is conducted to choice attribute which higher value. The technique is using score system that is very important (3), ordinary (2) and not important (1). Furthermore,

two experts will give judgments to choice the relevant of attributes. Based on above table we know that easy to supervise and team work has higher value that meaning both of attribute are very important. Other data be needed to evaluate is distance total and space usage from existing layout. Total distance used by existing layout is 778 m whereas space usage used is 203,5 $m^2$. AHP is employed to compare priority of the layouts in order to evaluate them. The evaluation result shows that type of manufacturing cell better than existing layout based on some criteria: easy to supervise (C1), team work (C2), space usage (C3) and total distance (C4) as summarized in Table 5.

**Table 5. Evaluation Result**

| Alternatives | Criteria | | | | Alternatives Priority |
|---|---|---|---|---|---|
| | C1 | C2 | C3 | C4 | |
| Manufacturing cell | 0,500 | 0,750 | 0,250 | 0,800 | 0,632 |
| Process (existing) layout | 0,500 | 0,250 | 0,750 | 0,200 | 0,268 |
| Criteria Priority | 0,105 | 0,240 | 0,205 | 0,450 | |

Finally, the application of this approach had important effect on the company's learning abilities. First, people changed their opinion on the use of such, as they called them. Theoretical approaches in process improvements. The results achieved made it clear that theoretical methods and frameworks, is well applied, may bring major benefits in organization and performance. Second, learning hoe to do it enabled them to extend manufacturing cell to other parts of the system, and to introduce further improvements in areas, e.g. work organization, health and safety and production planning and control methods.

## 5. CONCLUSIONS

Most studies in manufacturing cell design and application focus on specific approaches or prescriptions to solve part machine well defined problems. This study proposed an approach of manufacturing cell that combines a series method into an integrated and logical process. The proposed framework is comprised of four sequential approaches: selection of grouping method, grouping analysis, generating layout, and evaluation with AHP as main tool to solve multi criteria problems that emerging in logical process.

As initial step is selection of grouping method that necessary to determine how grouping the machines and the components should be worked. In this approach, method used to select the grouping method is AHP. Second approach is grouping analysis where is the grouping method selected used to cluster the machines based on the binary incidence matrix that obtained from the production processes. The generating layout is third approach to generate layout be needed intensity travel and space data. Objectives of layout are minimizing total travel distance and inter cells travel distance. Finally, evaluation approach as fourth approach is used to compare existing layout with proposed layout based manufacturing cell. Principle of evaluation approach is multi objective layout problem by using AHP. Qualitative factors is be generated by interview with personal who is understand the layout performance. The evaluation is initially identification some relevant factors.

It is recommended that the following ideas be examined in the future work in this area is included some real aspects of manufacturing environment (such as flexibility of manufacturing facilities as well as process routes and the stochastic nature of demand). The majority of the

works on multi objective manufacturing cell unify the various objectives in the form of single objective. The final result of such an approach is a compromise solution, whose non-dominance is not guaranteed.

## REFERENCES

Akturk, M.S., H.O. Balkose, 1996. "Part–Machine Grouping using A Multi–Objective Cluster Analysis", *International Journal of Production Research,* 34(8), pp. 2299–2315.

Ang, D.S., 1998. "Identifications of Part Families and Bottleneck Parts in Cellular Manufacturing", *Industrial Management & Data Systems,* 98(1), pp. 3–7.

Aurrecoechea, A., J.S. Busby, T. Nimmons, and G.M., Williams, 1994. "The Evaluation of Manufacturing Cell Design", *International Journal of Operations and Production Management*, 14 (1), pp. 60–74.

Baker, R.P., P.G. Maropoulos, 2000, "Cell Design and Continuous Improvement", *International Journal Computer Integrated Manufacturing*, 13(6), pp. 522–532.

Chan, F.T.S., K. Abhary, 1996. "Design and Evaluation of Automated Cellular Manufacturing Systems with Simulation Modelling and AHP Approach: A Case Study", *Journal of Integrated Manufacturing Systems*, 7 (6), pp. 39–52.

Silviera, G.D., 1999. "A Methodology of Implementation of Cellular Manufacturing", *International Journal of Production Research*, 37(2), pp. 467– 479.

Groover, M.P., 2001. *Automation, Production Systems and Computer Integrated Manufacturing*, Prentice Hall Inc, New Jersey.

Hadiguna, R.A., H. Setiawan, 2003. Desain dan Evaluasi Sel Manufaktur Multi Kriteria, *Jurnal Teknik Industri STT Musi–Palembang*, 3(1), pp. 21–32.

Hadiguna, R.A., M. Thahir, 2004. "Desain Formasi Sel Manufaktur dengan Mempertimbangkan Peralatan Pemindahan Bahan dan Mesin Posisi Tetap", *Jurnal Sains dan Teknologi,* 3(2), pp. 64–77.

Ham, I., K. Hitomi, T. Yoshida, 1985. *Group Technology: Applications to Production Management*, Kluwer-Nijhoff Publishing, Boston.

Heragu, S., 1997. *Facilities Design*, PWS Publishing Company, Boston, MA.

Mansouri, S.A., S.M.M. Husseini, S.T. Newman, 2000. "A Review of The Modern Approaches to Multi-Criteria Cell Design", *International Journal of Production Research,* 38(5), pp. 1201–1218.

Onwubolu, G.C., 1998. "Redesigning Jobshops to Cellular Manufacturing Systems", *Integrated Manufacturing Systems*, 9(6), pp. 377–382.

Singh, N., 1996. *System Approach to Computer-Integrated Design and Manufacturing*. John Wiley and Sons, Inc., N J.

Singgih, M. L, R.A. Hadiguna, 2003, *Pendekatan Pengklasteran Multi Objektif untuk Masalah Formasi Group Mesin/Komponen dalam Manufaktur Sellular*. Procedding Seminar Nasional TIMP–3, Teknik Industri ITS, Surabaya, Paper B9, pp. 53–57.

Siswanto, N., R.A. Hadiguna, 2003, *Kerangka Kerja Evaluasi Multi Kriteria dalam Masalah Tata Letak Fasilitas dengan Pendekatan AHP,* Procedding Seminar Nasional TIMP–3, Teknik Industri ITS, Surabaya, Paper B9, pp. 35–39.

Yang, J., R.H. Deane, 1994, Strategic Implications of Manufacturing Cell Formation Design, *Journal of Integrated Manufacturing Systems*, 5 (4/5), pp. 87–96.