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The Application of Cellular Manufacturing in Hard Disk Drive Industry

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Abstract

Cellular Manufacturing System (CMS) is used widely in multiple-product industries because CMS is the management of cells for flexibility of production system. Processes or machines are arranged in similar groups, and products are categorized in appropriate production groups. This study used CMS to apply to the hard disk drives industry. The goal is to increase productivity but decrease work flow distance by utilizing the management algorithm of cells. The group of cells yielded from this algorithm will be used in CMS, and the measure of performance for the groups of cells management are grouping efficacy, inter-cell production flow, and work flow distance. The systems of before and after applying CMS are simulated in order to investigate the change in production. There are two significant results obtained from this study. Four out of six product types improved in production: 2.29%, 16.22%, 3.39%, and 4.16%. In addition, the work flow distance of six product types decreased: 46.80%, 41.41%, 45.95%, 7.63%, 2.66%, and 13.61%.

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Keywords: CMS, Productivity, Algorithm, Work Flow Distance

1. Introduction

Hard drive production and manufacturing is an important business of Thailand, which can approximately be 32.2% of GDP. In addition, there is more expansion and competitive between manufacturers which lead to increase qualities and efficiency that would be a challenge for a company owner. However, the most significant problem is a completion in production line and management, which would be an impact for qualities and transportation costs of products. On the other hand, this research will show Cellular Manufacturing that can be called Cell Formation (CM), Machine Cell Formation (PF/MC) or Manufacturing Cell Design, which would produce more qualities and efficient resource usages. In addition, it can be used in verity of manufacturing, and

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the advantage is reducing distance flow of work and also increasing products. However, the most important problem of cell manufacturing management is how to define machine or a decision on which process should be proper in which manufacturing process that is rerated with case study which has many products of hard drive manufacturing and complicated transportation route. In order to solve these problems, Cell Formation can be adopted by grouped cell and defining priority for simulation and testing.

2. Theory and Case study research

This research is adopted Cell Formation which is used and grouped with similar machine or process in a near area. Adopting Cellular manufacturing has a common problem which is how to design production system. However, it can be divided into three methods:

(1) Grouped a similarity process
(2) Grouped a similarity machine
(3) Distribution of Grouped a similarity process and machine in to production line

Moreover, it can be considered in three ways:

(1) Grouped specimens before grouping machine
(2) Grouped machine by similar process before distributing specimens to cell manufacturing
(3) Grouped specimens and machine at the same time

There are many ways to design cell which has been dived into seven categories: [2]

(1) Part Coding System (PCS)—Using code number to identify shape or model such as Opitz and incorporate production base codes.
(2) Array-based Clustering—This method will be to sort machines by using Machine-Part Matrix that combine number one and zero (a ij). Number one will present work i that is produced be machine j, and number zero will present no work i that is produced by machine j. This solution is arraying on block diagonal form such as Rank Order Clustering (ROC-ROC2), Bond Energy Algorithm (BEA) and Direct Clustering Algorithm (DCA).
(3) Similarity Coefficient Approach (Hierarchical Clustering Method)—This solution will use similarity coefficient for a machine and use this number for grouping machine such as Single Linkage Clustering and Average Linkage Method.
(4) Graph Partitioning Approach—Machines will be represented by node and specimens which will be represented by arrow. The purpose of this method is to make a sub group that is independent and make it to cell manufacturing.
(5) Mathematical Programming Approach—This method is to adopt mathematic and programming together to assist Manufacturing group management that can be divided to four formation such as Linear Programming (LP), Linear and quadratic integer programming (LQP), Dynamic Programming (DP), and Goal Programming (GP).
(6) Heuristic Search Approach—Heuristic search Approach will be used if Mathematical Programming Approach has a limited of time calculation or cannott be solved by Linear Objective. An example of this method is Simulate Annealing, Genetic Algorithm and Tabu Search.
(7) AI-based Approach—This is an outstanding method in time calculation, which is more efficient to solve problem with high value such as Expert System and Neural Network.

Cellular manufacturing management problem is the problem that is interesting to plant layout researchers such as Chu and Tsai (1990) This paper examines three array-based clustering algorithms—rank order clustering (ROC), direct clustering analysis (DCA), and bond energy analysis (BEA)—for manufacturing cell formation. According to our test, bond energy analysis outperforms the other two methods, regardless of which measure or data set is used. If exceptional elements exist in the data set, the BEA algorithm also produces better results than the other two methods without any additional processing. The BEA can compete with other more complicated methods that have appeared in the literature. [5]

Tarun Gupta (1991) This paper presents results from an analytical study performed to determine the severity of chaining problem and other characteristics associated with the clustering process of four selected algorithms. The four algorithms are Single linkage clustering (SLINK), Average linkage clustering (ALINK), Weighted average linkage clustering (WLINK), and Complete linkage clustering (CLINK). A sample of fifty problems with randomly generated data sets was used to determine feasible solutions consisting of machine cells and corresponding part families from each of the four algorithms. A quantitative measure is proposed for evaluating the performance of different algorithms. The study concludes that the chaining effect for CLINK, WLINK, ALINK and SLINK progressively worsens from CLINK to SLINK in the same order. The study also provides important guidelines to designers of a CMS in selecting the most efficient algorithm for a given problem data. Several important statistical results are also presented. [10]

Joines (1996) This paper offers a comprehensive review and classification of techniques to manipulate part routing sequences for manufacturing cell formation. Individual techniques are aggregated into methodological groups including array-based clustering, hierarchical clustering, non-hierarchical clustering, graph theoretic approaches, artificial intelligence, math programming, and other heuristic approaches. Discussion of each model includes assumptions, analytic approach, performance criteria, and limitations. When possible, empirical results and comparisons of methods are provided. Evaluation measures are discussed in terms of their practical consequences on the cell design process. Recommendations are made for future research in the domain of stochastic search techniques. [6]

Onwubolu (1998) Grouping parts into families which can be produced by a cluster of machine cells is the cornerstone of cellular manufacturing, which in turn is the building block for flexible manufacturing systems. Cellular manufacturing is a group technology (GT) concept that has recently attracted the attention of manufacturing firms operating in a jobshop environment to consider redesigning their manufacturing systems so as to take advantage of increased throughput, and reductions in work-in-progress, set-up time, and lead times; leading to product quality and customer satisfaction. A similarity order clustering technique for the machine cell formation problem is presented. The procedure is compared with many existing procedures using eight well-known problems from the literature. The results show that the proposed procedure, which is attractive due to its simplicity, compares well with existing procedures and should be useful to practitioners and researchers. [8]

Moon, C. and Gen, M. (1999) In this paper, an approach is proposed for designing independent manufacturing cells in cellular manufacturing with alternative process plans and machine duplication consideration. Several manufacturing parameters, such as production volume, machine capacity, processing time, number of cells and cell size, are considered in the process. The problem is formulated as a 0–1 integer programming model and solved using genetic algorithm. It determines the machine cell, part family and process plan for each part simultaneously. [4]

Santos, N.R. and Araujo, L.O. (2002) A computational implementation of the production flow analysis, a software named GROUPTEC, for a small company has been proposed. Using GROUPTEC, a case study has been devised and applied to a company, belonging to aluminum-manufactured products branch. Four analyses of the production flow have been performed; that is, the factory flow analysis, group analysis, line analysis, and tool analysis. After the above technique application, the final results related to the technological cells and their components and part families and machinery groups lead to an adequate cell arrangement, with a grouping efficiency of approximately 98.8 per cent. A productivity gain of 30 per cent has been estimated with the time in movement of parts and queuing at the machine. [7]

Sugiyono, A. (2006) Layout can be defined as how to arrange the factory facilities on production floor to keep the production flow run smoothly. This case study was on production floor of PT.Cokro, with layout type that was process layout. Process Layout as the one of layout type arranges any kind of machine or other production facilities that has same type on one place. With this type of layout, company has many advantages such as flexibility on production process that has high variation. On the other hand, it also has a disadvantage effect, especially on the high cost of material handling. To reduce cost of material handling, a company should redesign their production floor layout. Cellular Manufacturing System as application of Group Technology can arrange the production facilities that require high variation process on part family product on the manufacture cell layout. With applying Cellular Manufacturing System, it will be more flexible to arrange the facilities. Besides that, the company can also figure out the reducing cost of the material handling and the length itself. Based on the data processing, using heuristics algorithm approach which is Bond Energy Algorithm (BEA), Rank Order Clustering (ROC), dan Rank Order Clustering 2 (ROC 2) we can conclude that BEA is the most suitable method to use, by classifying 6 machines and 6 components in to 2 manufacturing cell, which are the first cell (M4, M6, M1, M2, P2, P5, P6, P1) and second cell (M4, M6, M1, M3, M5, P3, P4). With this redesign, we can reduce the length of material handling almost 428.06 m and the cost of material handling almost Rp. 2,111,316.058 / month. [3]

Ponnambalam, S.G. et al. (2007) Cellular manufacturing system (CMS) is regarded as an efficient production strategy for batch type of production. CMS rests on the principle of grouping the machines into machine cells and parts into part families based on suitable similarity criteria. Usually zero-one machine-part incidence matrix (MPIM) obtained from the route sheet information is used to form machine cells. In this paper, an attempt has been made to solve the cell formation problem considering work load data, and a genetic algorithm (GA) is suggested to form machine cells and part families. The performance of the proposed algorithm is compared with existing algorithms such as K-means algorithm and modified ART1 algorithm found in the literature using a newly defined performance measure known as modified grouping efficiency (MGE). The proposed algorithm is tested with problems from open literature, and the results are compared with the existing algorithms found in the literature. The results support the better performance of the proposed algorithm. [9]

Weeratep Cheewaprasit and his colleagues have brought a Cellular manufacturing concept to be adopted with Wood furniture manufacturing industry to reduce time and increase customer demand which has been using Process Flow Analysis (PFA) for grouping product. Moreover, there are simulation to compare between result after study and result before study which found that it can reduce time. [1]

Because of the efficiency of cellular manufacturing and increasing product problem of case study and distance between transportation on factory. The researcher will adopt cellular manufacturing to create factory layout by using Cellular Manufacturing System and stimulate arena for testing and analyzing which would be increasing products and reducing distance work flow in a factory.

3. Solution

This research is adopted Array-Based Clustering to apply for cell management by two methods which are Rank Order Clustering (ROC) and Rank Order Clustering 2 (ROC 2) which are simple and uncomplicated.

Research Method Flowchart is displayed in Fig. 1.

3.1. Rank Order Clustering (ROC)

ROC method will apply Binary weight of row and column in matrix table to calculate total of Binary weight and arrange weight for descending.

Equation to determine the Binary weights are as follows

$$R_m = \sum_{m=1}^{M} 2^{M-m} a_{pm} \qquad (a_{pm} = 0,1) \qquad (1)$$

$$C_p = \sum_{i=1}^{P} 2^{P-p} a_{pm} \qquad (a_{pm} = 0,1) \qquad (2)$$

Algorithm calculating can be showed by

(Step 1) Assign binary weight 2^{M-m} to each column of the part-machine processing indicator matrix.

(Step 2) Determine the decimal equivalent R_m of the binary value of each row using the formula *(1)*.

(Step 3) Rank the rows decreasing order of their R_m value. Break ties arbitrarily. Rearrange the rows base on this ranking. If no rearrangement is necessary, stop; otherwise go to step 4.

(Step 4) For each rearranged row of the matrix, assign binary weight 2^{P-p}.

(Step 5) Determine the decimal equivalent C_p of the binary value of each column using the formula *(2)*.

(Step 6) Rank the columns decreasing order of their C_p value. Break ties arbitrarily. Rearrange the columns base on this ranking. If no rearrangement is necessary, stop; otherwise go to step 1.

(Step 7)

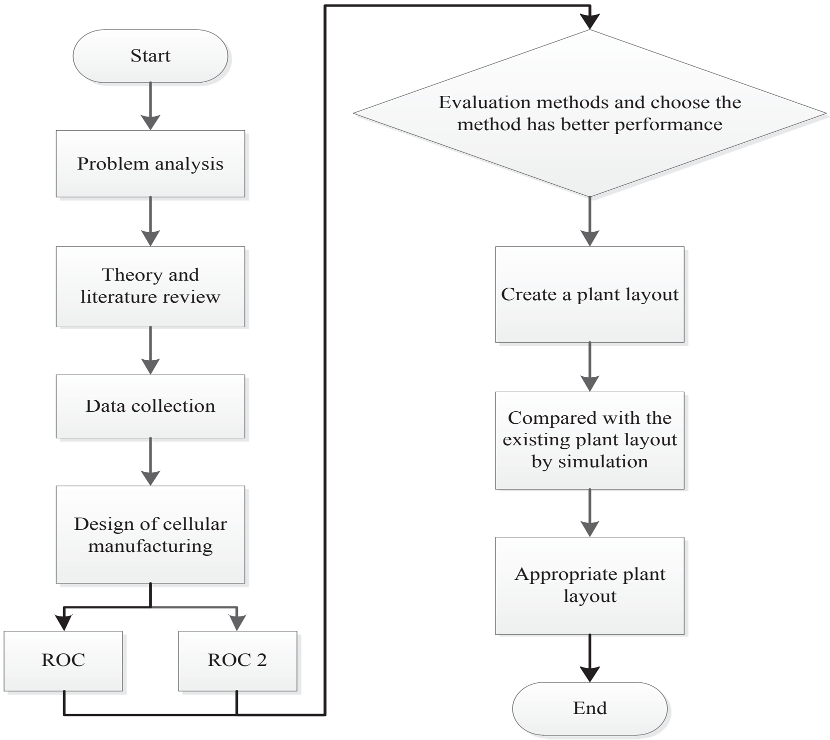

Fig. 1. Research Method Flowchart

3.2. Rank Order Clustering 2 (ROC 2)

Algorithm calculating can be showed by

(Step 1) Reorder of rows: Start from the last column of given machine-component incident matrix. Locate the row entries in this column. Move all rows with such entries to the head of the row list maintaining previous order of entries. Complete row ordering by going successively to the first column.

(Step 2) Reorder of columns: Start with last column (reordered row). Locate the columns entries in this row. Move all columns with such entries to the head of the column list maintaining previous order of entries. Complete column reordering by going successively to the current row.

(Step 3) Repeat step 1 and 2 till the matrix stabilizes.

The resulting final matrix ROC and ROC 2 shown in Fig. 2. and 3.

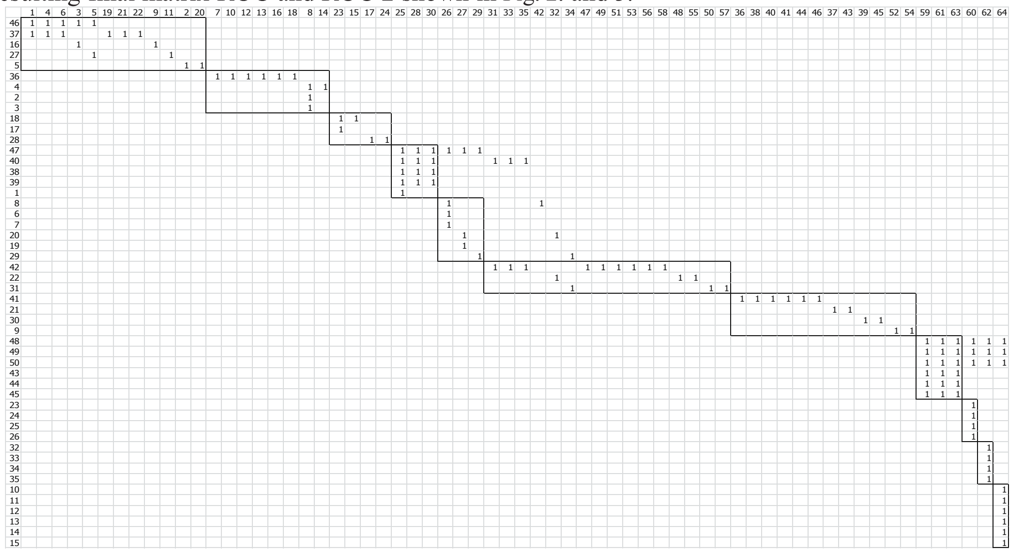

Fig. 2. Final Matrix ROC

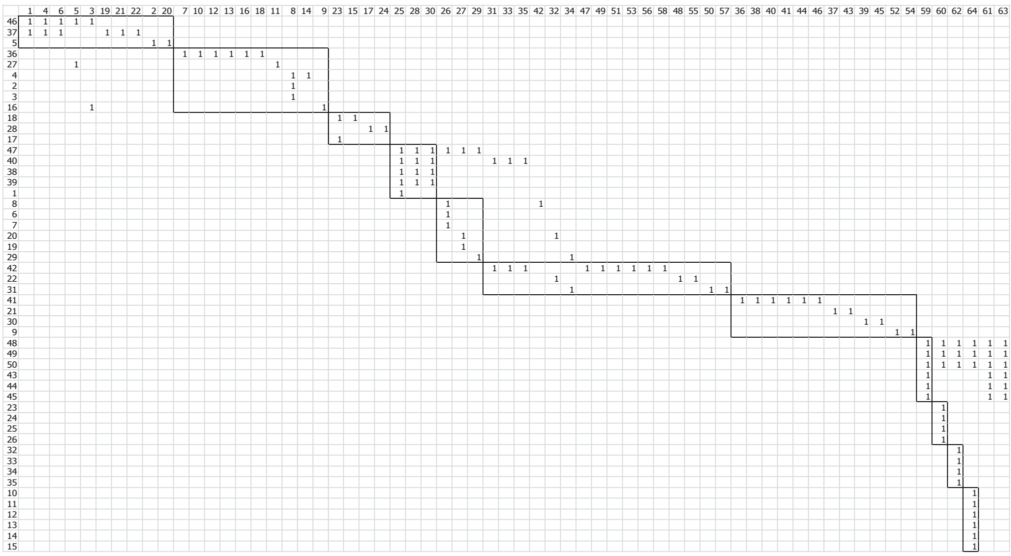

Fig. 3. Final Matrix ROC 2

3.3. Indicators grouped cell production.

(1) Grouping Efficacy

$$\text{Grouping Efficacy} = \left\{\frac{N_1 - N_1^{out}}{N_1 + N_0^{in}}\right\}$$

N_1 = Total of number one in matrix

N_1^{out} = Total of number one out of grouped cell

N_0^{in} = Total of number zero in grouped cell

(2) Intercells Production Flow

(3) Work Flow Distance

Table 1. Indicators Summary Table

Indicators Summary Table	Grouping Efficacy	Intercells Production Flow (*unit*)	Work Flow Distance (*m*)
ROC	0.388692580	34114	835.711
ROC 2	0.339222615	54468	849.702

As in Table 1, it shows that ROC has value less than ROC 2. As a result, it can conclude that ROC is better than ROC 2 in Grouping Efficacy, Intercells Production Flow and Work Flow Distance.

4. Evaluate the effectiveness of the plan produced by the simulation model

This method will simulate present situation to compare result with simulation from arena software which is shown on Fig. 4. and 5.

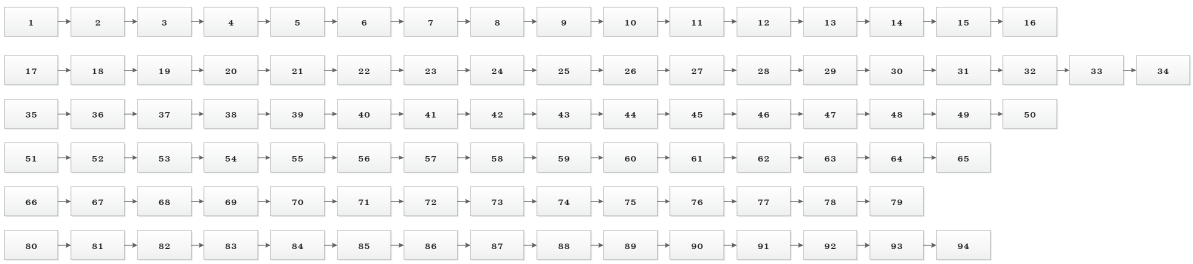

Fig. 4. Arena software simulation current model

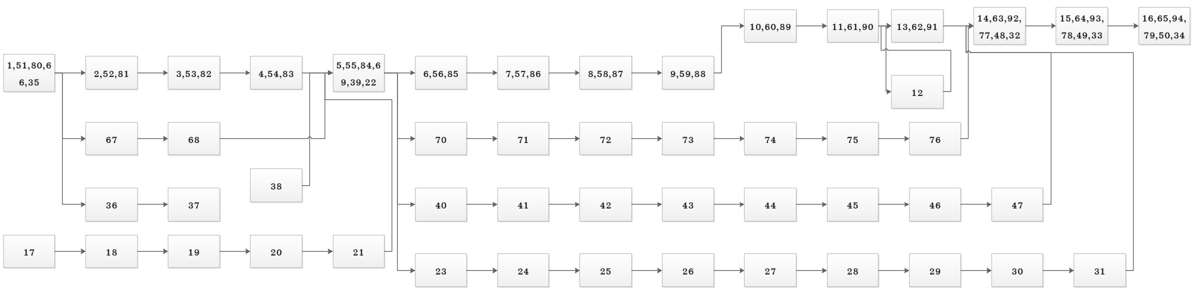

Fig. 5. Arena software simulation proposed model

A measure of the product output can be shown in Table 2.

Table 2. Production of the current model and the proposed model

Product Output	Current Model (*unit*)	Proposed Model (*unit*)	Increasing Product (*unit*)	Percentage (%)
A	83760	85680	1920	2.29
Ma	35904	41728	5824	16.22
Me	82480	85280	2800	3.39
Se	78400	78400	0	0.00
Sh	82720	86160	3440	4.16
V	46160	46160	0	0.00

Distance transportation of factory layout indicator will be considered with work flow which is calculated by Rectilinear Distance of product flow. As a result of the model proposed, distance value is reduced on every product which can be shown on Table 3.

Table 3. Total distance of the current layout and the proposed layout

Total distance	Current layout *(m)*	Proposed layout *(m)*	Reducing Distance (*m*)	Percentage (%)
A	198.684	105.692	92.992	46.80
Sh	163.527	95.807	67.72	41.41
Me	177.252	95.807	81.445	45.95
Ma	209.075	193.122	15.953	7.63
Se	211.031	205.423	5.608	2.66
V	161.892	139.86	22.032	13.61

5. Conclusion

This research is applying Cellular manufacturing in hard drive factory for case study which combines between production line layouts and processing for situation simulation to solve the problem of complicated work flow and try to increase products.

As a result of value testing, ROC method has less value than ROC2 which is better than ROC2. Those two methods are considered by three indicators that are Grouping Efficacy, Intercells Production Flow and Work Flow Distance.

Moreover, the efficiency of cell production simulation result of product A, Ma, Me, and Sh per week is increased by 1,920, 5,824, 2,800 and 3,440 units or 2.29%, 6.22%,3.39% and 4.16% which can be calculated to 13984 units of total increasing or 4.34%.

Moreover, every product work flow distance is shorter than before which is calculated to 92.99, 22.03, 5.61, 67.72, 15.95 and 81.45 meters by order product A, Ma, Me, Se, Sh and V or 46.80%, 41.41%, 45.95%, 7.63%, 2.66% and13.61% which are 26.34% of total work flow distance.

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