

## Grouping Maching using Genetic Algorithm for Dynamic Cell Layout Design

Y. Yogaswara, T.T. Dimiyati and R.R. Asri\*

Master Program of Industrial Engineering, Graduate Program Universitas Pasundan, Bandung, Indonesia

**ABSTRACT** – Changes in the manufacturing sector due to changes in shorter product life cycles, market demands and also use of the latest technology in the company, this will result in changes in process flow and also change the layout in the production section, causing dynamic layout problems. Dynamic layout problems can be solved by using a manufacturing cell formation method which has a high degree of flexibility. In this study, algorithms used for grouping machines into manufacturing cells are Direct Clustering Algorithm and Rank Order Clustering. Then it will be improved by using Genetic Algorithm. The Dynamic Modified Spanning Tree Algorithm is also used to sort machines into a layout with a single-row structure and determine the length of the planning time window in the future. The goals of this research is to get the best solution from the two methods of grouping machines/parts into manufacturing cells and to obtain improvement results using Genetic Algorithms. For the design industry, the resulting dynamic cell layout is expected to reduce production costs, save material handling, be efficient in material flow, which in turn will be able to compete globally.

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*Genetic algorithm*

*Modified spanning tree*

## INTRODUCTION

In the previous decade, many companies in the manufacturing sector experienced challenges due to globalization and high competition in the market. This problem arises due to changes in the shorter product life cycle, the increasing market demand for new and different variations, as well as changes in the use of the latest technology. Nowadays most of the manufacturing companies pay a lot of attention to increasing the flexibility of the machine layout as well as responsiveness to consumer demands. By considering the current trend, namely a shorter product life cycle, the company can work around this by increasing the variety of products produced to be wider and remain competitive with competitors. The wider the variety of products produced, the wider the machine will be. methods and materials used. This condition shows a very dynamic business pattern. This pattern will result in changes to the layout of the machine because it adapts to the product to be produced. One of the main techniques that can be applied to increase company flexibility is to use a Cellular Manufacturing System. Cellular Manufacturing System (CMS) is a direct application of the group technology philosophy in the manufacturing process. One of the main techniques that can be applied to increase company flexibility is to use a Cellular Manufacturing System. Cellular Manufacturing System (CMS) is a direct application of the group technology philosophy in the manufacturing process. One of the main techniques that can be applied to increase company flexibility is to use a Cellular Manufacturing System. Cellular Manufacturing System (CMS) is a direct application of the group technology philosophy in the manufacturing process.

*Group technology* can be the right solution to meet the challenges of flexibility and high efficiency. From the application of CMS the results that can be obtained are a reduction in the distance of material transfer, a reduction in product handling, work in process, inventory levels and lead times. Better factory layout will increase company efficiency and effectiveness [1]. Therefore, dynamic layout is one of the interesting things to do research compared to static layout because currently companies tend to make changes in the production department such as increasing production volume, changing product characteristics and adding new product types that will result in changes on the layout of the production section. This problem can be solved by making a trade-off between increasing material transfer costs and the expected cost of rearranging the machine layout.

In this study, to obtain a minimum cell layout, a research methodology was carried out using two methods. The methods used are Rank Order Clustering (ROC) and Direct Clustering Algorithm (DCA). Then the performance measurement will be carried out, namely grouping efficiency and grouping efficacy to determine the value of engine grouping efficiency and the comparison ratio between machines that are in the group and those that are not [2][3][4]. Genetic Algorithm (GA) method or Genetic Algorithm is a metaheuristic method that imitates the mechanism of natural selection and the process of natural evolution [5]. These heuristics are routinely used to generate useful optimal solutions for optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms, which generate solutions to optimization problems using techniques inspired by natural evolution, such

as inheritance, mutation, selection, and crossover [6]. The best results from the minimum machine grouping will be input data for the use of this GA method to optimize the distance from the material movement during the production process.

This research will be given a scenario of changes in which there is the addition of new types of products or changes in production volume. From this scenario, it will be continued with the calculation of the Dynamic Modified Spanning Tree (DMoST) Algorithm, which is a combination of the Modified Spanning Tree Algorithm for determining the order of machines and the Silver-Meal Algorithm for time window planning [7]. From the results of the research methodology, a trade-off will be made between the increase in the cost of moving materials and the expected cost of rearranging the machine layout. About 20% – 50% of the total factory operating costs are material handling costs, so with an effective layout design will be able to reduce these costs by at least 10% – 30% [8]. If the layout is effective then the company will be able to make savings and focus on other problems. Based on the above, research on dynamic layout is an interesting thing to do. The objective of this research is to find the best solution from the two methods of grouping machines/parts into manufacturing cells and get the results of improvements using Genetic Algorithms, in addition to getting a dynamic cell layout design for the future that has considered increasing production volumes and adding new types of products.

## METHODS

In this study a problem-solving model is needed to be able to provide a clear picture of the problem-solving steps that will be carried out. Here is a dynamic cell layout troubleshooting flowchart:

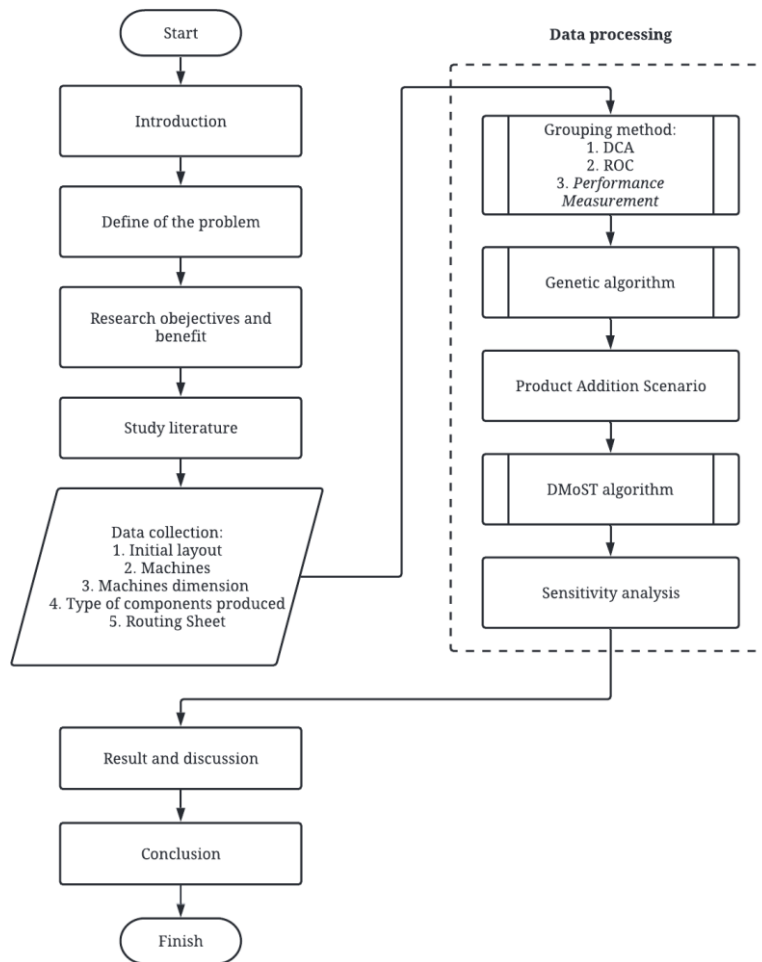


Figure 1. Flowchart problem solving model.

## CASE STUDY

This study uses the object of research conducted by Rajak [5]. This company is engaged in the production of machines or appropriate technology tools (direct manufacturers). On the other hand, it also produces machinery for processing agricultural, plantation, forestry, animal husbandry, marine products, handicraft product processing machinery, food and beverage processors, machinery for laboratories, machinery for industry and so on.

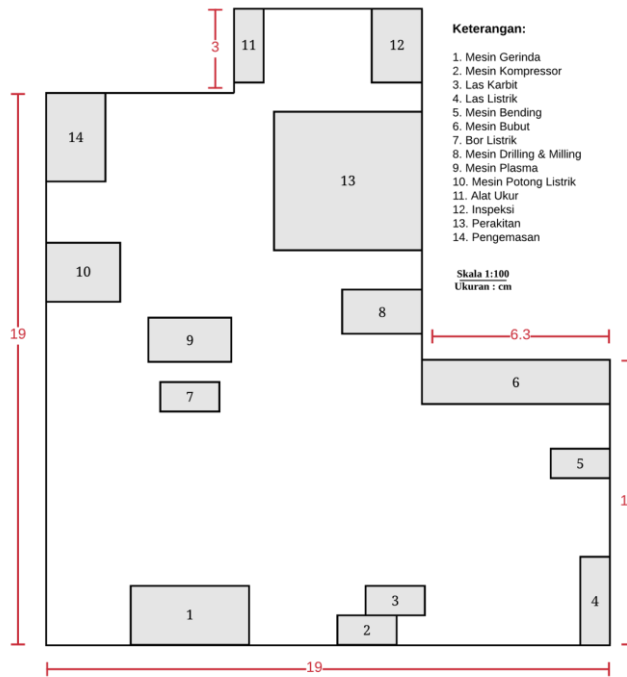


Figure 2. Initial Layout.

RESULT AND DISCUSSION

Manufacturing cell formation

Production Flow Analysis (PFA) or commonly known as incidence matrix is a systematic procedure that analyzes information from the route of the manufacturing process of a part [6]. This PFA consists of inputs 0 and 1. Input (1) indicates that the machine is used while input (0) indicates that the machine is not used for processing the part in question. Two methods are used so that there are alternative choices and the alternative with the minimum total material handling cost will be chosen. On top of that, the use of the DCA and ROC methods is relatively easy compared to other Cellular Manufacturing System methods.

Table 1 Result of DCA and ROC.

M/P	4	10	5	6	7	8	9	1	2	3	11	14	12	13	Σ
11	1	1	1	1	1	1	1	1	1	1	1	0	0	0	9
1	1	1	1	1	0	1	1	1	0	1	0	0	1	0	1
12	1	1	1	0	0	1	1	0	1	0	0	1	0	0	2
9	1	0	1	1	0	0	1	0	1	1	1	0	0	0	2
5	1	1	0	0	0	0	1	1	1	0	1	0	0	0	6
10	0	1	1	0	1	1	0	1	0	0	0	0	0	0	1
3	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1
4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2
8	0	0	0	1	1	0	0	0	0	0	0	0	0	0	7
13	0	0	0	0	0	0	0	0	0	0	0	1	0	1	5
2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	11
6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
14	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Σ	4	4	3	6	5	5	5	5	5	6	3	2	2	3	58

M/P	10	1	4	9	2	11	5	8	6	3	7	12	14	13
11	1	1	1	1	1	1	1	1	1	1	1	0	0	0
5	1	1	1	1	1	1	0	0	0	0	0	0	0	0
1	1	1	1	1	0	0	1	1	1	1	0	1	0	0
10	1	1	0	0	0	0	1	1	0	0	1	0	0	0
9	0	0	1	1	1	1	1	0	1	1	0	0	0	0
12	1	0	1	1	1	0	1	1	0	0	0	0	1	1
7	0	0	1	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	1	0	0	0
3	0	0	0	0	0	0	0	0	1	0	0	1	0	0
2	0	0	0	0	0	0	0	0	0	0	1	0	0	0
6	0	0	0	0	0	0	0	0	0	0	1	0	0	0
4	1	0	0	0	0	0	0	1	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	1
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0

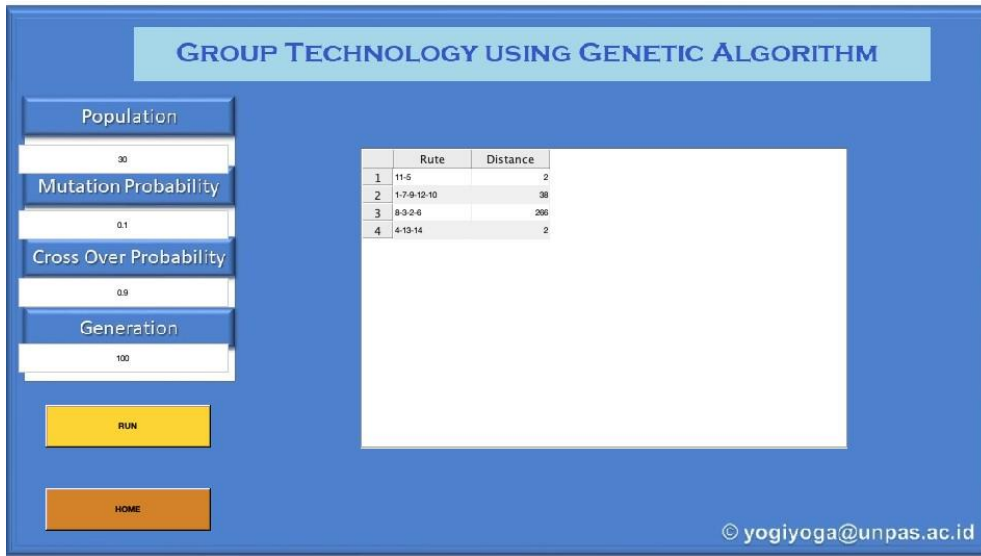
DCA Algorithm grouped the machines into 2 cells. Cell 1 consists of machines (11, 1, 12, 9, 5, and 10) and components (4, 10, 5, 6, 7, 8, 9, 1, 2, 3, and 11). Cell 2 consists of machines (3, 4, 8, 13, 2, 6, 7 and 14) and components (14, 12, and 13).

ROC Algorithm grouped the machines into 4 cells, cell 1 consists of machines (11, 5) with components (10, 1, 4, 9, 2,

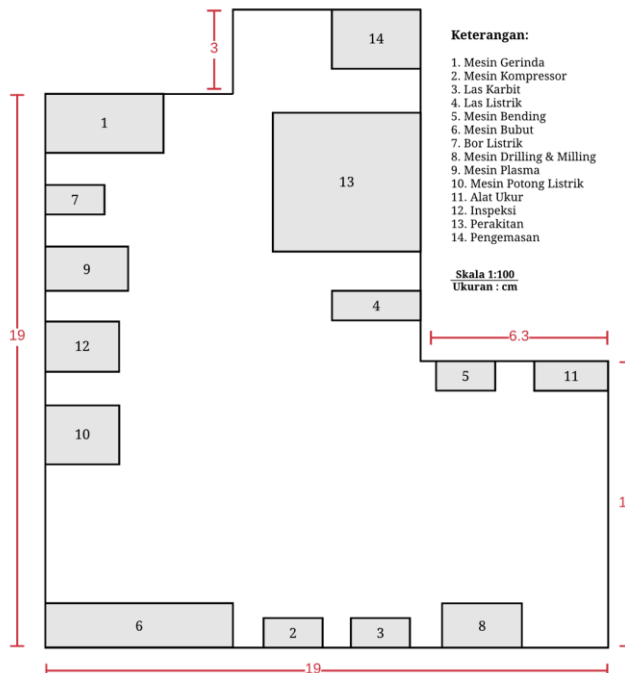
11). Cell 2 consists of machines (1, 10, 9, 12, 7) with components (5, 8, 6, 3, 7). Cell 3 consists of machines (8, 3, 2, 6) with components (7, 12) and cell 4 consists of machines (4, 13, 14) with components (14, 13).

**Genetic Algorithm**

Genetic algorithm is a search method that imitates the process of biological evolution, then developed for machine layout problems with the aim of shortening the distance that will be traversed by raw materials to finished products which ultimately shortens material flow. Chromosomes from the formation of manufacturing cells are entered into Microsoft Excel which is then connected to the MATLAB software to help calculate the Genetic Algorithm. The goal is that calculations can be carried out more quickly and precisely. In this study, 2 experiments were carried out. The results from the formation of manufacturing cells with the ROC and DCA Algorithms are then reprocessed with the Genetic Algorithm, to provide even better results. After the experiment, the machine sequence chosen is ROC consists of 4 cells [11-5][1-10-9-12-7][8-3-2-6][4-13 -14], with the minimum material handling cost of 308. So from that sequence a new layout proposal was made.



**Figure 3.** Genetic Algorithm Result.



**Figure 4.** New Layout Proposal.

### Product Change Scenario

In fact, changes often occur on the company's production floor. This is due to new types of products being produced or changes in the company's production volume. This product change scenario is based on previously known changes, namely in each period there is the addition of one new product type and an increase in production volume.

This product change scenario is applied based on the proposed layout, which is the result of grouping machines into manufacturing cells with ROC algorithm, which has been improved with Genetic Algorithms. In the Time Window calculation, 2 research scenarios will be carried out based on rearrangement costs. It is assumed that the planning period is 10 periods with rearrangement costs for the first scenario of 9,100,000, and rearrangement costs for the second scenario of 2,800,000. These costs include cost for workers to move machines, tools hired to move machines, machine installations and others.

### Dynamic Modified Spanning Tree

In fact, changes often occur on the production floor. This is due to new types of products being produced or changes in the company's production volume. This product change scenario is based on previously known changes, namely in each period there is the addition of one new product type and an increase in production volume. This product change scenario is applied based on the proposed layout, which is the result of grouping machines into manufacturing cells with ROC algorithm which has been improved with Genetic Algorithms.

The DMoST algorithm is a combination of the modified spanning tree (MST) algorithm for setting machine layout in manufacturing cells with the Silver-Meal (SM) algorithm for determining the planning time window length.

### Machine Sorting Result in Single-row Machine Layout

From the results of the proximity weight matrix calculation, the machine sequence is obtained using the MST Algorithm. The machine sequence is based on the proximity between the machines.

**Table 2.** Machine Sequence in Single-Row Machine Layout.

Period	Machine Order	Total MHC Each Configuration
1	11-10-9-1-4-6-8-2-14-7-5-3-13-12	1,637,033
2	13-3-8-6-10-11-9-1-4-5-7-2-14-12	1,707,792
3	14-7-5-4-2-3-13-8-6-10-11-9-1-12	1,699,725
4	11-9-5-1-10-6-8-4-12-13-3-14-2-7	1,374,709
5	14-5-7-3-13-2-8-6-4-12-1-9-10-11	1,114,388
6	4-7-14-3-13-12-1-2-8-6-5-9-10-11	1,336,519
7	11-10-9-5-6-8-2-1-12-13-3-7-14-4	1,608,957
8	11-10-9-5-1-12-13-3-7-4-14-2-8-6	1,650,913
9	11-10-9-5-1-12-13-3-4-7-14-2-8-6	1.608.009
10	4-14-7-3-13-12-1-2-8-6-5-9-10-11	1,563,511

### Time Window Planning with Silver-Meal Algorithm

In determining the time window planning, some information that has previously been calculated or determined is needed, namely the total cost of moving materials for each configuration per period, the cost of rearrangement or rearrangement costs. In this research, two time window planning scenarios will be carried out. The first scenario with the cost of resetting the layout is made high while the second scenario with the cost of resetting the layout is made low. The results of the two time window planning scenarios and the cost per period of layout configuration will be described in detail as follows. In this first scenario, the rearrangement cost is made low at 2,800,000. The calculation of the planning time window for the first scenario in more detail can be seen in the following table:

**Table 3.** Determining the Length of Time Window Planning 1.

Period	T	MHC Each Configuration WK	M (T-1)Wk	M [ $\sum(T-)Wk$ ]	TRC(T)	TRC(T)/T
1	1	1,637,033	0	0	2,800,000	2,800,000
2	2	1,707,792	1,707,792	1,707,792	4,507,792	2,253,896
3	3	1,699,725	3,399,449	5,107,241	7,907,241	2,635,747
3	1	1,699,725	0	0	2,800,000	2,800,000
4	2	1,374,709	1,374,709	1,374,709	4,174,709	2,087,354
5	3	1,114,388	2,228,776	3,603,484	6,403,484	2,134,495
5	1	1,114,388	0	0	2,800,000	2,800,000
6	2	1,336,519	1,336,519	1,336,519	4,136,519	2,068,259
7	3	1,608,957	3,217,915	4,554,433	7,354,433	2,451,478
7	1	1,608,957	0	0	2,800,000	2,800,000
8	2	1,650,913	1,650,913	1,650,913	4,450,913	2,225,456
9	3	1.608.009	3,216,017	4,866,930	7,666,930	2,555,643
9	1	1.608.009	0	0	2,800,000	2,800,000
10	2	1,563,511	1,563,511	1,563,511	4,363,511	2,181,755

From the calculation of the length of time window planning, a dynamic cell layout design has been obtained by considering the changes that occur according to the scenario. The following are the results of the calculation of the Silver-Meal algorithm which have been summarized in table below:

**Table 4.** Silver-Meal Algorithm Calculation Results 1.

Period	Flow Weight	Time Window	Total MHC
1	1,637,033	3,344,825	1,707,792
2	1,707,792	-	-
3	1,699,725	3,074,433	1,374,709
4	1,374,709	-	-
5	1,114,388	2,450,907	1,336,519
6	1,336,519	-	-
7	1,608,957	3,259,870	1,650,913
8	1,650,913	-	-
9	1.608.009	3,171,519	1,563,511
10	1,563,511	-	-
Total	15,301,554	15,301,554	7,633,443

In this second scenario, the cost of rearrangement is made high, which is 9,100,000 for one re-arrangement. The calculation of the time window planning for this second scenario in more detail can be seen in the following table:

**Table 5.** Determining the Length of Time Window Planning 2.

Period	T	MHC Each Configuration WK	M (T-1)Wk	M $[\sum(T-)Wk]$	TRC(T)	TRC(T)/T
1	1	1,637,033	0	0	9,100,000	9,100,000
2	2	1,707,792	1,707,792	1,707,792	10,807,792	5,403,896
3	3	1,699,725	3,399,449	5,107,241	14,207,241	4,735,747
4	4	1,374,709	4,124,126	9,231,367	18,331,367	4,582,842
5	5	1,114,388	4,457,551	13,688,918	22,788,918	4,557,784
6	6	1,336,519	6,682,593	20,371,511	29,471,511	4,911,919
6	1	1,336,519	0	0	9,100,000	9,100,000
7	2	1,608,957	1,608,957	1,608,957	10,708,957	5,354,479
8	3	1,650,913	3,301,826	4,910,783	14,010,783	4,670,261
9	4	1,608,009	4,824,026	9,734,809	18,834,809	4,708,702
9	1	1,608,009	0	0	9,100,000	9,100,000
10	2	1,563,511	1,563,511	1,563,511	12,371,302	6,185,651

From the calculation of the length of time window planning, a dynamic cell layout design has been obtained by considering the changes that occur according to the scenario. The following are the results of the calculation of the Silver- Meal algorithm which have been summarized in table below:

**Table 6.** Silver-Meal Algorithm Calculation Results 2.

Period	Flow Weight	Time Window	Total MHC
1	1,637,033	7,533,646	5,896.613
2	1,707,792	-	-
3	1,699,725	-	-
4	1,374,709	-	-
5	1,114,388	-	-
6	1,336,519	7,767,908	6,431,390
7	1,608,957	-	-
8	1,650,913	-	-
9	1,608,009	-	-
10	1,563,511	-	-
Total	15,301,554	15,301,554	12,328.002

**Sensitivity Analysis**

This analysis was conducted to see the sensitivity to the effect of parameter changes, namely rearrangement cost on the total cost. From the sensitivity analysis table above, it shows that the total rearrangement cost parameter is the most influential if the rearrangement cost changes from 2,800,000 to 9,100,000 or around 325%, the cost increase reaches up to 95%. While the parameters of material handling costs, material transfer costs and total costs, the increase that occurs is almost the same, namely by 61%-62%. Therefore, if the rearrangement cost increases, the number of layouts will decrease, whereas if the rearrangement cost decreases, the number of layouts will increase. In line with the Silver-Meal Algorithm, the longer the planning time window will reduce the frequency of layout rearrangements but increase the cost of moving materials, vice versa.

**Table 7.** Sensitivity Analysis.

Parameter	Scenario 1	Scenario 2	Ascension
	Rearrangement Cost		
	2,800,000	9,100,000	
Relayout	5	3	-40%
Material Handling Cost	7,633,443	12,328.002	61%
Material Transfer Cost	3,235,083,526	5,224,656,761	61%
Total Rearrangement Cost	14,000,000	27,300,000	95%
Total Cost	3,249,083,526	5,251,956,761	62%

## CONCLUSION

The results from the formation of manufacturing cells with the Rank Order Clustering and Direct Clustering Algorithm are then reprocessed with the Genetic Algorithm, to provide better results. From data processing using Genetic Algorithm, there are some changes in the order of machines in certain cells in both algorithms, although not many machine sequences have changed and that is the best result of both algorithms. To find out the best solution for these two machine grouping methods, a comparison was made based on the material handling cost parameters of each algorithm and it turned out that the best solution was Rank Order Clustering.

To design dynamic cell layouts in the future, several experiments were carried out using scenarios of adding production volumes and adding new types of products, it is known that if rearrangement costs increase, the number of layouts will decrease, whereas if rearrangement costs decrease, the number of layouts will increase. In line with the Silver-Meal Algorithm, the longer the planning time window will reduce the frequency of layout rearrangements but increase the cost of moving materials. On the other hand, the smaller the length of the planning time window, it means that the frequency of the layout arrangement will be more frequent, which in turn will increase the cost of setting the layout but will reduce the cost of moving materials. So it must be known the optimal point between the number of layouts and material handling costs in order to obtain a layout that reduces material handling costs the most.

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