DYNAMIC MODIFIED SPANNING TREE ALGORITHM FOR SINGLE-ROW DYNAMIC FACILITY LAYOUT PROBLEM

Yogi Yogaswara

Industrial Engineering Department, Pasundan University
yogiyoga@unpas.ac.id

ABSTRACT

Changes that occur as a result of costumized product or product mix will result in frequent changes in the process flow of each product that will ultimately change the layout. Thereby in future periods activity redesigning existing layout is a must and will become more frequent. Dynamic facility layout is the right choice to accommodate the changes that occurred to make a trade off between the rearrangement cost and material handling cost. This paper discusses an algorithm developed for single-row dynamic facility layout. Test results using some hypothetical scenarios of data shows the algorithm has a better performance for determining the time window length and the resulting total cost.

***Keywords** : Dynamic Facility Layout, single-row, rearrangement cost, material handling cost, time window.*

1. INTRODUCTION

Layout problem is not only done to design a new manufacturing system, but also to develop, consolidate or modify existing systems. In the static layout problems (Static Layout Problem/ SLP) assumed that the business environment is relatively stable so that information about the activities of the plant in the future, which include what products will be produced and the machine that will be used is known at the time specified facility design decisions. In addition, the composition of the products (product mix) and the volume can be said to be relatively constant. In these conditions (static and deterministic environment) layout design can last up to five years (Heragu, 1997). Such conditions can be justified on traditional manufacturing systems but does not apply to the modern system where the business environment is changing rapidly.

In the Dynamic Layout Problem (DLP), business conditions showed a very dynamic pattern. Nicol and Hollier, in 1983, observed that the effective age of a facility layout of manufacturing systems is defined as the time from the layout to be installed for at least a third engine was replaced two years. And estimated age effective layout becomes shorter in the future. This is caused by the pace of technological innovation, and the frequency of changes in product design and functionality of products desired by consumers are higher for the future. Thereby in future periods, activities redesigning existing layout is a must and will become more frequent.

The importance of dynamic facility planning is reinforced by the many studies that have been conducted. Rosenblatt (1986) used dynamic Programming to obtain the optimal trade off between the transfer cost of materials and the cost of rearranging the layout of the approach to the warehouse locations dynamic analysis model and applied with the best layout combination of the successive periods of time and used as well as a static layout. However, for a large number of departments that the optimal solution could not be achieved (Lacksonen, 1994).

Urban (1993) developed a heuristic algorithm dynamic facility layout with process layout types, to try to resolve the problem without using dynamic programa well as the optimal solution of the quadratic assignment problem (QAP). In these studies, Urban argued forecast window concept is used to define the layout on a period to include load factor data of subsequent periods.

The study was conducted by Yang and Peters (1998) tried to design a layout with a flexible machine process layout type for dynamic and uncertainty production environments. In the study mentioned that in order to optimize it is to make a trade-off between the increase in the material handling cost as required by changes in the cost of resetting the desired machine layout to the changes adaption. The procedure for determining the length of planning time window approach is to use the analogy of the lot size determining Silver-Meal algorithm.

This research conducted to design an algorithm for dynamic facility layout by observing the changes represented in the scenario. Further expected from this scenario can be applied to a real situation in the real world, especially in industries that have high enough sensitivity to changes in the business environment.

2. THE DYNAMIC FACILITY LAYOUT PROBLEM OVERVIEW

The review is very important because it gives a sense of what the actual effect of the changes to the existing layout. This step is necessary to look at the parameters that influence the changes attributable to the layout design.

On the issue dynamic facility layout arrangement, there are two important cost incurred in connection with changes to the layout, which is as follows :

a. Material Handling Cost
   The cost depends on the volume of material flow, cost of moving between departments, and the distance between departments. Structuring appropriate department position will minimize the total material handling cost
b. Rearrangement/shifting cost
c. Rearrangement/shifting cost, consist of :
   1) Variable cost
      Variable costs associated with material handling costs of the department concerned (eg the cost of packing and moving workers and equipment, the cost of restoration of the building and planning departments concerned electricity, etc.).
   2) Fixed Cost
      Fixed costs such as the rearrangement cost regardless of which department is transferred (such as getting permits removal costs, certain costs of planning and preparation, etc.).

2.1 Perubahan Tata Letak Fasilitas

The changes that may occurred within a facility layout, ie :

a. Addition of the production demand volume.
   - Increase the number of certain facilities
   - Fixed Product Routing but increasing the frequency of the material flow.
b. The existence of a new product / new production line / addition of new products.
   As a result of this change is the addition of the order process (routing) of new products.
c. Changes in the production process caused by the type of product that is changing.
   As a result of this change is to change the routing of products.

2.2 Optimum dan Heuristic Approach

Optimum solution approach used for solving dynamic facility layout problem is very limited, because it requires a long computation time and the only facility capable of handling the amount slightly. One method that is often used optimal solution is Dynamic Programming.

In the heuristic approach, a faster computation time and number of facilities in the layout can be handled much more. This heuristic approach is more focused on better results than the previous results, although not Optimum but can be said to approach the Optimum results. Heuristic algorithm for dynamic layout problem include the proposed heuristic algorithm Rosenblatt (1986). While on a flexible machine layout proposed by Yang and Peters (1998) by taking into account the orientation of the engine and the use of lot-sizing methods for determining the length of planning time window.

Several methods have been developed to answer dynamic facility layout problem is (Balakrishnan, 1998) :

- *Cutting Planes* (Bonniger [1983])
- *Branch and Bound Algorithm* (Pardalos and Crouse [1989])

- *Cut trees* (Gomory and Hu [1961] and developed by Montreuil B. and Ratliff H.D [1989])
- *Dynamic Programming* (Rosenblatt, 1986)
- *Heuristic Facility Layout Algorithm* (Urban, 1993)

2.3 Single-Row dan Multi-Row Layout

Single-row layout is often called one-dimensional space allocation problem. As the name implies, problem-row layout of the facility is arranged in a linear and a single line, for details can be seen in Figure 1. The problem of single-row layout is the other machines layout on the one hand from the automated guided vehicle (AGV) on the factory floor and the assignment of the arrival of the plane to the airport gate, so it should be minimized entire distance traveled by passengers from the airport to assign flight with significant interaction at a distance proximity gate.

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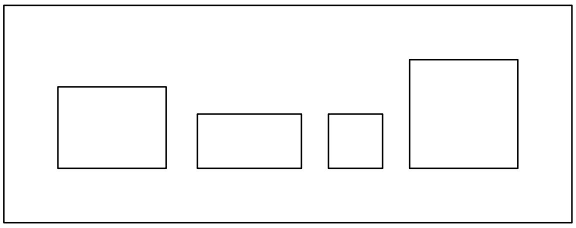

Figure 1. single-row Layout

The model for single-issue layout row can be explained as follows :

Model assumption :

1) Facility has the shape of a cube or rectangle
2) Facilities placed in a straight line
3) Machine Orientation has been known
4) There is no a limiting form of the building where the machine will be located
5) There is no a change of the type of product, the volume of any type and the production process during the planning period.

This model can be used to formulate the facility layout problem for equal length or not the same. The objective function of this model is the minimization of the total material handling cost between facilities. Limiting function ensures that no two overlapping facilities

Multi-row layout is often called the probem of allocating two-dimensional space. Some issues of multi-row layout is a matter of the control panel layout , machine layout problem in an automated manufacturing system, the design of the keyboard on a typewriter, and office layout (Burkard,1984) in Heragu (1997). Many models have been developed to formulate the problem, such as the quadratic assignment problem (QAP) which is proposed by Koopmans and Beckman [1957], the model mixed-integer linear programming proposed by Love and Wong (1976), the quadratic model of the set covering by Bazaraa (1975) and non- linear models with absolute terms in the objective function and the barrier by Heragu (1992). In Figure 2 it can be seen an illustration of a multi-row layout.

This model can be used to formulate the facility layout problem for equal length or not the same. The objective function of this model is the minimization of the total material handling cost between facilities. Limiting function ensures that no two overlapping facilities.

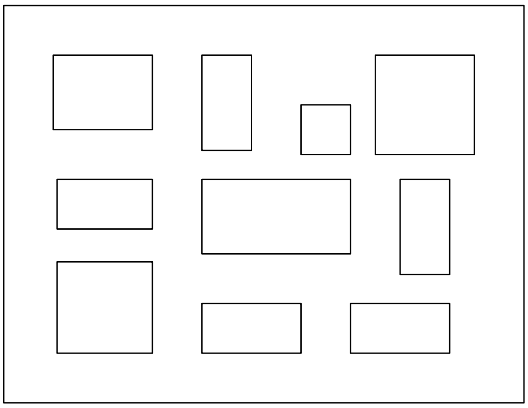

Figure 2. *Multi-Row Layout*

The assumption of this model is the size and shape of the facilities (departments) and wide all the same, and the material flow is constant during the planning period.

3. DYNAMIC MODIFIED SPANNING TREE ALGORITHM

3.1 Notation and Formulation

The following is the notation and terminology used in the formulation Dynamic Modified Spanning Tree algorithm for single-row dynamic facility layout.

$$f'_{ijk} = \left(f_{ijk}\right)\left[d_{ijk} + \frac{1}{2}\left(l_{ik} + l_{jk}\right)\right]$$
(1)

where :

f'_{ijk} = adjacency weight for machine *i* to *j* at period-*k*

$[f_{ijk}]$ = material flow matrix at period-*k*

$[d_{ijk}]$ = distance matrix at period-*k*

l_{ik}. = length of machine *i* period-*k*.

l_{jk} = length of machine *j* period-*k*

k = period-*k*

$$\frac{TRC_T}{T} = \frac{R + M\left[\sum_{k=1}^{T}(k-1)W_k\right]}{T}$$
(2)

where :

TRC_T = The total relevant cost for period *T*

R = Layout rearrangement cost

M = Material Handling Cost

W_k = Total material handling cost *of* layout configuration at period-*k*

*(k-*1*)* = Starting Period where tentative planning time window length is calculated

T = Last period are included in tentative planning time window length

k = period -*k*

$\sum_{k=1}^{T} W_k$ = jumlah dari total *OMH* untuk tiap konfigurasi tata letak untuk seluruh period-*k.*

[f'_{ijk}] = Adjacency weight matrix

L_k = Length of time window planning with period-*k*

3.2 The Modified Spanning Tree Basic Algortihm

Modified Spanning Tree algorithm is used to design the layout of a manufacturing cell with single-row structure to generate the sequence in the engine department or facility layout. Ordering department or in the layout engine, noticed no changes to the production flow (routing), so the layout results with the Modified Spanning Tree is no longer efficient static if it is still used for some future period.

This algorithm belongs to the static layout problem with single-row structure. Modified Spanning Tree algorithm is quite simple, and very similar to the Spanning Tree algorithm. Some of the following definitions will clarify the terminology used (Heragu, 1997) :

If the graph G = (V, E) is a set of vertex (V) and edges (E) with each edge associated with two peaks. The peak is sometimes referenced as nodes and edges as arcs.

From the a complete graph showing irregular edges and the weight of each edge, Spanning Tree algorithm is used to find the set of edges, namely :

a) Each vertex is connected directly to each edge.
b) The sum of the weight of this edge is the minimization or maximization depends on the selected criteria.
c) The edge is not in the form of a cycle, there is a unique section between each pair of peaks in other words Spanning Tree algorithm seeks to find a "tree" (the set of edges associated with each vertex to each other without forming a cycle) that span the entire peak where the sum of edge weights is a minimization or maximization.

If the department or the machine is assumed to be the peak and each pair of machines connected by the proximity of an edge, the edge is equal to the weight of the flow times the distance between the proximity relations department or machine, then the Modified Spanning Tree algorithm tries to find the order of the number of departments or machine weights of edge associated with the proximity of the maximum departemeb or machine. Note that idea is to minimize the total flow times distance, therefore, to maximize the amount of weight or engine department proximity means spouse or engine department that has a great flow value placed close together. Determine the sequence of single - row machine layout. As well as spanning tree algorithm, Modified Spanning Tree algorithm to form a " tree ". After all that is done like that on every peak except the first and last in the sequence has exactly 2 edges. The first peak and last only

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one. Modified Spanning Tree Algorithm is not optimal because it does not follow that reasoning is not based on the weight of proximity, and also just specify the order of the department or the engine, the addition of a factor to be considered in forming a layout, such as the distance between the machine and whether the department or the layout formed a linear or semicircular. For example, when an Automated Guided Vehicle (AGV) is used, typically linear AGV for maximum operating efficiency. In other cases, when a robot is used as a means of material handling, the layout is semicircular because when the one-way circular or semicircular, the robot can access the entire machine.

The Steps of *Modified Spanning Tree* Basic Algorithm, ie :

Step (1)
Flow matrix [f_{ij}], distance matrix [d_{ij}], and length of machine l_i, Calculate adjacency weight matrix [$f_{ij}^{'}$], where :

$$f_{ij}^{'} = \left(f_{ij}\right)\left[d_{ij} + \frac{1}{2}\left(l_i + l_j\right)\right] \qquad (3)$$

Step (2)
Found the biggest element in [$f_{ij}^{'}$] and relation *i*, *j.* At this problem pair *i*, *j* as i^*, j^*. Connect the machine i^*, j^*. Set

$$f_{i^*j^*}^{'} = f_{j^*i^*}^{'} = -\infty$$
(4)

Step (3)
Found the biggest element $f_{i^*k^*}^{'} = f_{j^*l^*}^{'}$ in row i^*, j^* from matrix [$f_{ij}^{'}$]. If $f_{i^*k}^{/} \geq f_{j^*l}^{/}$ connect *k* to i^*, move row i^* and column i^* form matrix [$f_{ij}^{'}$] and set $i^* = k$. Otherwise *l* at j^*, move row j^* and column j^* from matrix [$f_{ij}^{'}$] and set $j^* = l$. Set $f_{i^*j^*}^{'} = f_{j^*i^*}^{'} = -\infty$

Langkah (4)
Repeat step 3 until all machine are connected. The Sequence of machine determine machine setting.

3.3 Silver-Meal *Lot-Sizing* Algorithm to Determine The Length of Time Window Planning

Silver-Meal algorithm in determining the length of planning time window is an analogy with one of the important processes in material requirements planning is lotting process. Lotting process is a process to determine the number of components of items to be provided for the needs of the production process. This process is an important basis in a material requirements plan. Therefore the use of appropriate methods of lot size will be very helpful and affect its effectiveness.

Lot size means the size of the lot size / size of the items to be ordered that status is determined by consideration of the expenses occurred . Costs are considered in this order cost dancarrying cost. Taking into account both the cost of the lot size method will minimize the total cost thereof.

For the dynamic facility layout problem, the lot size, the cost of inventory and setup costs is equivalent to the length of the planning time window, material handling costs and expenses resetting layout. In other words, the increase in planning time window would increase the cost of removal of the material but it will reduce the cost of reorganizing the layout and vice versa.

In determining the length of planning time window for dynamic facility layout design, the length of planning time window will be associated with the rearrangement of cost and material handling cost. The smaller the length of planning time window, which means more frequent resetting layout, material handling costs will decrease, but increase the cost of rearranging the layout. Conversely, the greater the length of planning time window will reduce the frequency of resetting the layout, which means reducing the cost of rearranging the layout, but the resulting increase in the cost of material handling. For the length of planning time necessary to find the right window to minimize the total material handling cost.

To get a good layout is to make a trade off between the cost of the removal of material at a cost of changes to the planning layout planned time window. The problem now is to find a set of planning the best time window for dynamic manufacturing cell layout with single-row structure, to determine the value of T for each planning window. Given that T = 0 indicates a dynamic layout strategy with a new layout that is determined each period to adjust to the changing needs of production, while T = "length of horizon planning" strategy shows a layout that can be accepted in whole future production scenario.

As well as in material requirements planning system goal of this method is to minimize the total costs per period.

Length of time window is determined by addition the planning of material handling cost of each configuration layout several periods in a row as the length of time window is tentatively planning.

The addition is done continuously until total costs (cost of material handling and layout rearrangement costs) divided by the same number of periods in which the costs of material handling configuration layout planning including long-time window into the tentative final total costs per period are still declining.

This method does not guarantee that a minimum of material handling cost can be optimally achieved, because this method does not perform further calculations if the total cost per period increases have been achieved.

3.4 *Dynamic Modified Spanning Tree* (DMST) Algorithm

This algorithm is basically an amalgamation of Modified Spanning Tree algorithm for sorting machine into the layout with single - row structure with algorithms Silver - Meal (SM) for the determination of the length of planning time window including the determination of the total costs for the resulting layout.

At Dynamic Modified Spanning Tree algorithm (DMST), structured layout generated single - row account of changes to the product routing in future periods.

In order to accommodate these changes , then the dynamic MST algorithm is added to the method of determining the length of planning time window to provide information about the data flow dynamic - deterministic production throughout the planning period . To select the method of determining the length of planning time window is better, it is necessary to use other methods for comparison.

These changes will be implemented into a plan events or hypothetical scenarios to determine the performance DMST algorithm to be designed.

Relationships with other attributes are as follows : the smaller the length of planning time window, which means more frequent resetting layout, material handling costs will decrease, but increase the cost of rearranging the layout. Conversely, the greater the length of planning time window will reduce the frequency of resetting the layout, which means reducing the cost of rearranging the layout, but the resulting increase in the cost of material handling. For the length of planning time necessary to find the right window to minimize the total material handling cost.
To further elucidate the relationship can be seen in Figure 3 .

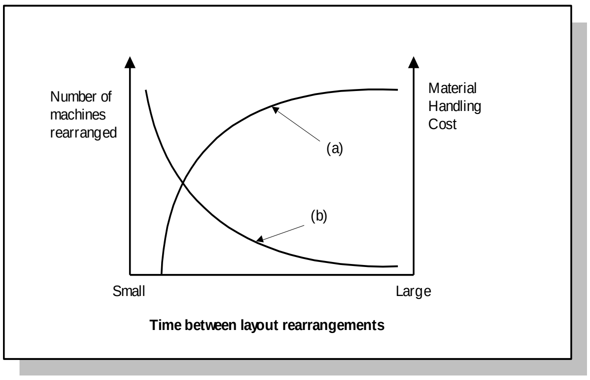

Figure 3 Relationship between attributes of Dynamic Machine Layout

3.5 Dynamic MoST Algorithm Steps

From analogy result in the previous section, it can be arranged an algorithm as follows :

1. Set the flow matrix for each period-*k*, [f_{ijk}], distance matrix [d_{ijk}], and length of machine l_{ik}.
2. Calculate adjacency weight matrix [f'_{ijk}], where :
$$f'_{ijk} = (f_{ijk})\left[d_{ijk} + \frac{1}{2}(l_{ik} + l_{jk})\right]$$
3. Found the biggest element in [f'_{ijk}]
4. Connected machine i^*_k, j^*_k.
5. Set $f'_{i^*j^*k} = f'_{j^*i^*k} = -\infty$

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6. Found the biggest element $f'_{i^*m^*} f'_{j^*n^*}$ in row i^*_k, j^*_k from matrix [f'_{ijk}].
7. If $f'_{i^*mk} \geq f'_{j^*nk}$ connected m to i^*_k, move row i^*_k and column i^*_k form matrix [f'_{ijk}].
8. Set $i^*_k = m_k$.
9. Otherwise connected n to j^*_k,
10. move row j^*_k and column j^*_k form matrix [f'_{ijk}].
11. Set $j^*_k = n_k$.
12. Set $f'_{i^*j^*k} = f'_{j^*i^*k} = -\infty$
13. Repeat step 3 until all machine are connected. The Sequence of machine determine machine setting.
14. If all the machines have been sorted in period k, then repeat steps 1 through period k = T.
15. Calculate total material handling cost each layout configuration each period, W_k, obtained from :
    f'_{ijk} , or with other words set $f'_{ijk} = W_k$
16. Determine layout rearrangement cost.
17. Calculate Total cost per period, *TRC(T)/T*, with formulation (2), i.e :
$$\frac{TRC_T}{T} = \frac{R + M\left[\sum_{k=1}^{T}(k-1)W_k\right]}{T}$$
18. Add Material Handling Cost each configuration at next period, k + 1, and calculate total cost per period, *TRC(T)/T.*
19. If $C(k,T+1) > C(k,T)$ or in other words :
$$\frac{TRC(T+1)}{T+1} > \frac{TRC(T)}{T}$$
    The length of time window planning, $L_k = \sum_{k=1}^{T} W_k$
20. Otherwise, repeat step 18.
21. Keep going until period $k = T$.
22. Select the appropriate layout configuration with L_k.
23. Calculate Total Cost of Layout.
24. Finish.

4. PERFORMANCE ANALYSIS

To determine the performance of the algorithm DMST, then created a hypothetical scenario that describes the data type of product changes that will result in changes to the layout in each period in the planning period as shown in Table 1 to Table 6.

Table 1
Adjacency Weight Matrix [f'_{ijk}] at period 1

To / From	1	2	3	4	5	6
1	0	34	20	22	17	0
2	34	0	15	0	0	12
3	20	15	0	20	15	0
4	22	0	20	0	17	0
5	17	0	15	17	0	12
6	0	12	0	0	12	0

Table 2
Adjacency Weight Matrix [f'_{ijk}] at period 2

To / From	1	2	3	4	5	6
1	0	17	0	0	0	17
2	17	0	15	17	12	0
3	0	15	0	0	30	0
4	0	17	0	0	17	17
5	0	12	30	17	0	0
6	17	0	0	17	0	0

Table 3
Adjacency Weight Matrix [f'_{ijk}] at period 3

To / From	1	2	3	4	5	6
1	0	17	40	0	0	0
2	17	0	15	17	12	12
3	40	15	0	40	0	15
4	0	17	40	0	0	0
5	0	12	0	0	0	0
6	0	12	15	0	0	0

Table 4
Adjacency Weight Matrix [f'_{ijk}] at period 4

To / From	1	2	3	4	5	6
1	0	34	20	44	17	17
2	34	0	45	17	12	12
3	20	45	0	40	0	15
4	44	17	40	0	17	17
5	17	12	0	17	0	0
6	17	12	15	17	0	0

Table 5
Adjacency Weight Matrix [f'_{ijk}] at period 5

To / From	1	2	3	4	5	6
1	0	34	0	0	17	0
2	34	0	0	34	0	0
3	0	0	0	20	15	15
4	0	34	20	0	0	34
5	17	0	15	0	0	0
6	0	0	15	34	0	0

Table 6
Adjacency Weight Matrix [f'_{ijk}] at period 6

To / From	1	2	3	4	5	6
1	0	51	80	66	0	34
2	51	0	45	34	36	12
3	80	45	0	40	15	0
4	66	34	40	0	0	17
5	0	36	15	0	0	24
6	34	12	0	17	24	0

By using the results obtained DMST algorithm sorting department in single-row layout as shown in Table 7.

Table 7 Department Sequence in *single-row* layout

Period	Department Sequence in Single-Row Layout	Total MH cost each configuration
1	5 – 3 – 4 – 1 – 2 – 6	100
2	3 – 5 – 4 – 2 – 1 – 6	98
3	1 – 3 – 4 – 2 – 5 – 6	109
4	6 – 2 – 3 – 4 – 1 – 5	158
5	5 – 1 – 2 – 4 – 6 – 3	134
6	4 – 1 – 3 – 2 – 5 – 6	251

The next step is to determine the length of planning time window.
The calculation of the length of planning time window with Silver-Meal algorithm can be seen in Table 10 and Table 11 in the Appendix.

Figure 4 shows the amount each period for determination of the length of planning time window selected.

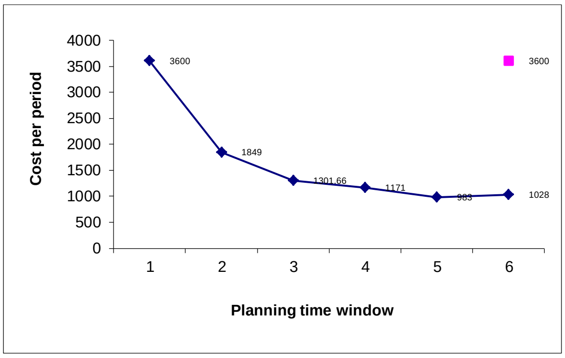

Figure 5
Cost per Period

To determine the performance of the algorithm DMST, then do a comparison with the heuristic algorithm of Urban (1993), the results of the implementation can be seen in Table 9.

Table 9
Comparizon of Silver-Meal Algorithm Implementation Solution and Heuristik Urban Algorithm

Method	L_km	Department Sequence in Single-Row Layout	Cost Per Period	Total cost
Silver-Meal	1-5	5 – 1 – 2 – 4 – 6 – 3	983	8526
	6	4 – 1 – 3 – 2 – 5 – 6	3600	
Urban	2	5 – 2 – 1 – 3 – 4 – 6	232	15760

From the Table 9 clearly shows that the Silver-Meal algorithm approach better its performance with a total cost of which is smaller than the Urban algorithms. This is due to the algorithm has a mechanism Urban summation of the width of the window a certain forecast of up to m = T. However in Table 9 algorithms Urban has a smaller cost per period is equal to 232 Silver-Meal algorithm than having the smallest cost per period, which amounted to 983.

Silver-Meal algorithm has better performance reasons, the value of search mechanism smallest cost per period can be determined directly by adding the cost of the removal of material each configuration for each period. While the Urban algorithms such mechanisms do not exist, and just do not try to get the minimum value of the cost per period by adding the load factor for each subsequent period, starting with m = 1 to m = 6.

The layout generated by considering the change in the type of product , has the minimum total cost is equal to 8526 consisting of cost of material handling and rearrangement costs in 1326 amounted to 7200 to reset twice layout . The resulting layout is derived from the calculation of the length of planning time window before, so that in the period in which the total cost per period is decreased and the minimum is the layout that will be selected. The changes that occur due to changes in product routing different for each period , so that the layout change to follow these changes.

Based on the length of time window is obtained planning the layout design of the layout used is generated for the first planning period is the 5th period that the order of the department [5 - 1 – 2 - 4 - 6 – 3].

While at the last planning period , obtained with the layout department sequence [4 - 1 - 3 – 2 - 5 – 6] at 6th period by using the previous layout as the initial layout.

In general it can be said that the layout of the configuration changes that greatly vary from period 1 to period 6.

In plants that have the type of manufacturing process that is constantly changing or orders that continue to change for some time, this case is suitable to be applied. With the change of the order, the company will continue to update the type of product, the machine layout considerations relating to changes in the type of products will greatly assist management decisions in terms of doing the type of product changes.

The layout generated using the DMST algorithm can be seen in Figure 6.

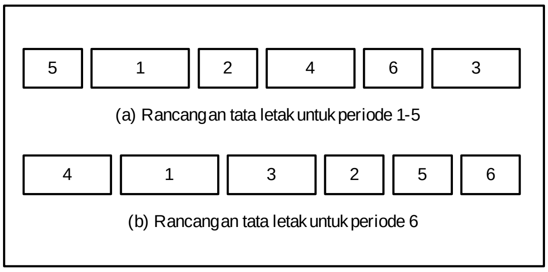

Figure 6
Result of The DMST Algorithm Layout

5. CONCLUSION

Algorithm for dynamic facility layout single-row based on the Modified Spanning Tree algorithm (static) for setting the layout and sorting department, and Silver-Meal Algorithm for the determination of the length of planning time window.

At Dynamic Modified Spanning Tree algorithm (DMST), the order of the number of machines specified adjacency weight of the maximum weight of each machine with the aim of minimizing the overall flow times distance or material handling costs.

In the Silver - Meal algorithm, the greater the length of planning time window will reduce the frequency of rearrangement layout which reduces layout rearrangement but resulted in an increased cost of material handling costs. Vice versa, the smaller the length of planning time window, meaning more frequent rearrangement layout that will reduce material handling costs but add to the layout rearrangement costs.

The layout generated using the DMST algorithm can be seen in Figure 6.

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Appendix :

Table 10
Determine The Length of *Time Window*
With Silver-Meal Algorithm

Period	T	MH cost each Config. W_k	$M(T\text{-}1)W_k$	$M\left[\sum(T-1)W_k\right]$	*TRC(T)*	*TRC(T)/T*
1	1	100	0	0	3600	3600.00
2	2	98	98	98	3698	1849.00
3	3	109	207	305	3905	1301.66
4	4	158	474	779	4684	1171.00
5	5	134	536	1315	4915	983.00
6	**6**	**251**	**1255**	**2570**	**6170**	**1028.00**
6	1	251	0	0	3600	3600.00

Table 11
Result of Silver-Meal Algorithm

Periode	1	2	3	4	5	6	Total
Flow Weight	100	98	109	158	134	251	850
Time window	599					251	850
MH cost	499	401	292	134	0	0	1326

Material Handling Cost = (total MH cost) x (cost per distance unit for flow unit)
= (7271) x (1) = 1326

Rearrangement cost = (rearrangement frequency) x (rearrangement cost)
= (2) x (3600) = 7200

Total Cost = (material handling cost) + (rearrangement cost)
= (1326) + (7200) = 8526