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Dynamic Approach of Facility Layout Considering Replacement Analysis

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Abstract: ***Facility planning is concerned with the design, layout, and position of people, machines and activities of a system within a physical spatial environment. Facility planning is very important in a manufacturing process due to their effect in achieving an efficient product flow. It is estimated that between 30%- 60% of the whole costs in manufacturing is related to material handling. This cost can be reduced until 30% through an effective facility planning. Proper analysis of facility layout design could improve the performance of production line by decrease blockage rate, minimize material handling cost, reduces idle time, raise the efficiency and utilization of labor, equipment and space. In this paper we are dealing with one aspect of the material handling cost in the context of plant layout. Whereas previously the plant layout and their replacement problem have been treated as a static problem, we provide here a solution for the dynamic plant layout problem. The dynamic programming formulation presented can be used to solve the dynamic plant layout problem in an optimal manner.***

Keywords: Facility Planning, Material handling, Optimization method, Replacement analysis, Plant Layout

1. Introduction

In today's dynamic markket, organizations must be adaptive to market fluctuations. In addition, studies show that material-handling cost makes up between 30 to 60 percent of the total operating cost. Therefore, this paper considers the problem of arranging and rearranging manufacturing facilities, when there are changes in product mix and demand, such that the sum of material handling and rearrangement costs is minimized. This problem is called the dynamic plant layout problem (DPLP). In this paper, the authors develop method of dynamic plant layout considering with replacement analysis.

This paper investigates the layout problem based on multi-period planning horizons. During these horizons, the material-handling flow between the different departments in the layout may change. This necessitates a more sophisticated approach than the static plant layout problem (SPLP) approach. The dynamic plant layout problem (DPLP) extends the SPLP by considering the changes in material handling flow over multiple periods and the costs of rearranging the layout The importance of good layout planning can be gauged from the fact that over $250 billion is spent in the US alone on layouts that require planning and re-planning and that 20-50 % of the total operating expenses within manufacturing can be attributed to material handling [14]. In an environment where material-handling flow does not change over a long time, a static layout analysis would be sufficient. However, in today's market based and dynamic environment, such flows can change quickly necessitating dynamic layout analysis. The work done by Rosenblatt [13] has generally accepted as the first serious approach to model and solve DPLP. He used dynamic programming to solve the problem with each layout in each period being a state and each period a stage. The main problem with his model is the determination of alternative layouts to use in stage. Urban [15] proposes an approach using a steepest-descent pairwise exchange heuristic similar to CRAFT. Lacksonen and Enscore [8] also studied the DPLP. They modeled the problem as a modified quadratic assignment problem. Conway and Venkataramanan [5] and Balakrishnan and Cheng [1] applied genetic algorithms to solve DPLP. The application of Tabu search to DPLP is shown by Kaku and Mazzola [7]. Lacksonen [9, 10], and Montreuil and Venkatadri [12] consider dynamic layout when the sizes of departments are unequal. Baykasoglu and Gindy [3] have developed a simulated annealing for the DPLP. Erel et al. [6] also proposed several heuristics for dynamic plant layout problem by using dynamic programming and simulated annealing. Balakrishnan et al. [2] also proposed hybrid genetic algorithm for DPLP. Since it uses dynamic programming in crossover, it is called GADP. Baykasoglu et al. [4] applied ant colony to solve DPLP. They consider both budget constrained and unconstrained DPLP. Mckendall and Shnag [11] also proposed the hybrid ant systems for dynamic plant layout problem.

2. The Dynamic Plant Layout Problem

The DPLP problem extends the well-known static plant layout problem where a group of departments are arranged into layout such that the sum of the costs of flow between departments is minimized under the assumption of material flows between departments are constant over time. The dynamic plant layout problem ignores the above assumption. The dynamic problem involves selecting a static layout for each period and then deciding whether to change to a different layout in the next period. If the shifting costs are low, the layout configuration would tend to change more often to retain material handling efficiency. The reverse is true for high shifting costs where we would relocation to avoid the associated shifting or rearrangement costs. The mathematical model for DPLP is as follows [8]:

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$$\text{Min} \sum_{s=1}^{T}\sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{N}\sum_{l=1}^{N} A_{ijkslt}X_{ijs}X_{klt}$$

Subjected to:

$$\sum_{i=1}^{N} X_{ijs} = 1 \qquad j = 1 \ldots. N,$$
$$= 1 \ldots \ldots. T \qquad (1)$$
$$\sum_{j=1}^{N} X_{ijs} = 1 \qquad j = 1 \ldots. N, s$$
$$= 1 \ldots \ldots. T \qquad (2)$$
$$X_{ijs} \in (0,1) \qquad \forall\, i, j, s$$

Where

X_{ijs} = 1 if department i is in location j at time s, otherwise 0

$A_{ijsklt} = C^1_{ikt} d_{jl}$ if (i≠k or j≠1) and s=t

$= C^2_{ijt} d_{jl}$ if (i=k or j=1) and s=t

$= C^3_{ikt} d_{jl}$ if (i≠k or j≠1) and s=t+1

= 0 otherwise

N is the number of departments or locations, T is the number of time periods. C^1_{ikt} is the flow cost between departments i and k in time t, C^2_{ijt} is the cost of assigning department i to location j in time t, C^3_{ikt} is the cost of changing a location from department i to department k in consecutive time periods, and d_{jl} is distance between locations j and l.

The objective function minimizes the total cost of layout rearrangements and the cost of material flow between departments during the planning horizon. The constraint set (1) ensures that each location is assigned only one department at each period, and the constraint set (2) ensures that exactly one department is assigned to each location at each period.

3. Replacement Model

Replacement problem fall into two categories depending upon the life pattern of the equipment involved that is whether the equipment wear out or become obsolete with time (because of constant use or new technological developments) or suddenly fails.

For items that wear out, the problem is to balance the cost of new equipment against the cost of maintaining efficiency on the old and /or cost due to the loss of efficiency. Though no general solution is possible, models have been constructed and solutions have been derived using simplified assumption about the condition of the problem.

A separate but similar, problem involves the replacement of items such as electric bulb, radio tubes etc. of equipment which does not deteriorate with time but suddenly fails. The problem in this case, is of finding which items to replace and whether or not to repave them in a group and, if so, when. The objective is to minimize the sum of the cost of the item, cost of replacing the item and cost associated with failure of item. There is still another situation in which replacement become necessary. This is obsolescence due to new discoveries and better design of equipment. The equipment needs replacement not because it no longer performs to the design standard, but because more modern equipment perform higher standard.

Quite often that repair and maintenance cost of items increase with time and a stage may come when these costs become so high that it is more economical to replace the item by a new one. Since both of these costs tend to increase with time, they are grouped while analyzing a problem.

Replacement of Item that Deteriorate i.e., Whose Maintenance Cost Increase with Time

Case 1: When time 't' is a continuous variable

Let C = Capital cost of item,

S = Scrap value of the item,

T_{avg} = Average annual cost of the item,

n = Number of year the item is to be in use,

f (t) = Operating and maintenance cost of the item at time t.

It is desired to find the value of n that minimizes T (n), the total cost incurred during n year.

Annual cost of the item at any time t = capita cost – scrap value + maintenance cost at time t = C – S + f (t).

Now total maintenance cost incurred during n year = $\int_0^n f(t) \,.\, dt$

Total cost incurred during n year T (n) = C – S + $\int_0^n f(t) \,.\, dt$

Average annual cost incurred on the item T_{avg} = 1/n [C – S + $\int_0^n f(t) \,.\, dt$]

Now we shall find that value of n for which T_{avg} is minimum. Differentiating previous equation w.r.t. n, we get

$d/dn\,(T_{avg}) = -1/n^2 . (C\text{-}S) - 1/n^2 \int_0^n f(t) \,.\, dt + 1/n.f(n)$.

$d/dn\,(T_{avg}) = 0$, we have

$f(n) = T_{avg} = 1/n\,[C - S + \int_0^n f(t) \,.\, dt]$

Thus the item should be replaced when the average annual cost to date becomes equal to the current maintenance cost. Using this result we can decide when to replace an item provided an explicit expression is given for the maintenance and repair costs.

Case 2: when time 't' is a discrete variable

In this case, the total cost incurred during n year,

$T(n) = C - S + \int_0^n f(t) \,.\, dt$

Average annual cost incurred on the item,

$f(n) = 1/n[C - S + \int_0^n f(t) \,.\, dt]$

'n' is optimal at the east average annual cost.

Table 1: Result

Initialization	Input data: Maintenance Cost of each machine, Resale Value of each machine, Flow matrix and Distance matrix.

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Replacement analysis	It is found that machine should be replaced at which year.
Calculation of Transporting Cost	It is found that arrangement A-B-C-…..N is optimum flow path.
Result	Found the optimum and fresh layout of A-B-C----N
Benefit	We can save the shifting cost. Best and economic flow pattern is obtained. Hence overall cost of product will be decreases.

4. Conclusion

The developed algorithms and computer system after this research will illustrate the significance of the design for flexible layout. The studies performed in this research, along with the developed computer systems (considering replacement model), will be extremely useful for researchers and designers to appreciate the effect of layout design decision, especially flexible layout design. This layout result will be a low total material handling cost, low shifting cost (shifting of machine after replacement analysis) and will help the industry to maintain a competitive edge.

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