Dynamic From-Between Chart: A Solution to Dynamic Facility Layout Problems

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1. Introduction

According to [1], the material handling cost comprises about 20-50% of the total operating cost of the facility layout. Typical research on facility layout concentrate on static layout problems where from-to charts are used to evaluate the layout. These layouts are not flexible enough to accommodate any future changes in production. Research on dynamic facility layout also has used the concept of static from-to chart. A more efficient method of modifying the layout is to perform rearrangement whenever there are changes in production rates or product mix. This necessitates a development of methodology that exactly reflects these uncertainties. This paper introduces the concept of dynamic from-between chart to determine the layout redesign points. An algorithm that minimizes the total cost of material handling and redesign has also been developed. A genetic algorithm approach is then used to validate the use of dynamic from-between chart. Effectiveness of the developed methodology is illustrated using a case study that resulted in a consistently improved performance compared to traditional methods in terms of cost.

2. Experiment, Results, Discussion and Significance

The Dynamic from-between chart is generated based on process plan and expected production rates. As the production demands are continuously changing, the demand data along with the process plan can be used to develop a dynamic from-between chart. Let $f_r(t)$ represent the product demand function for product 'r' for time period ranging from time t = 0 to t = 'T'. The function $g_{ij}(t)$ for the dynamic flow between any two facility locations 'i' and 'j' is given by the summation of flows between 'i' and 'j' for all products from 1 to M.

$$g_{ij}(t) = \sum_{r=1}^{M} f_r(t) \quad X_{ijr} \qquad (1)$$

The dynamic from-between chart is a plot of all $g_{ij}(t)$ with respect to time't', where i can have values from 1 to N-1 facilities and j from i+1 to N. X_{ijr} is a binary number which has a value 1 when there is flow between facilities 'i' and 'j' for product r. The general equation that determines the cost Z of the layout, when no redesign is performed is given by:

$$Z = \sum_{i=1}^{i=N-1} \sum_{j=i+1}^{N} \int_{t=0}^{t=T} g_{ij}(t)\,dt * D_{ij} * C \qquad (2)$$

Where, D_{ij} – the distance between facilities 'i' and 'j'
C – Cost of material handling/unit distance

The objective function requires the minimization of 'Z', the total cost. If 'm-1' numbers of redesigns are performed at periods t_1, t_2, t_3, $t_4 \ldots t_{m-1}$, then three cost components have to be considered. The first component is the cost of material handling for each period. The second component is the fixed cost associated with the dismantling and movement of the departments. The third component is the variable cost associated with departments which depends on the distance and difficulty to move each department. Let $P_x = \{t_0, t_1, t_2, t_{3 \ldots} t_{m-1}, t_m=T\}$, the set of time intervals at which redesign is performed. Where, t_m=T = end of planning horizon. Thus number of redesigns, $P_0 = t_0$, $P_1 = t_1 \ldots P_m = t_{m-1} = T$. The sum of the costs of material handling for each period is given by:

$$M = \sum_{k=0}^{k=m-1} \sum_{i=1}^{i=N-1} \sum_{j=i+1}^{N} \int_{t=t_k}^{t=t_{k+1}} g_{ij}(t)\,dt * D_{ijk} * C \qquad (3)$$

Let $D = \{D_0, D_1, D_2 \ldots D_m\}$ represent the set of layout designs corresponding to each period. D_0 represents the current layout and D_m represents the layout corresponding to the last period. Then the fixed cost of rearrangement is given by:

$$F = \sum_{k=0}^{k=m-1} F_{k,k+1} \qquad (4)$$

The variable rearrangement cost is given by the summation of the variable costs for transition from one period to the next period. The variable costs depend on the distance through which the departments are moved during each redesign.

$$V = \sum_{k=0}^{k=m-1} V_{k,k+1} \quad (5)$$

For a problem with 'N' departments/locations, the variable cost for transition from period 'k' to 'k+1' is given by:

$$V_{k,k+1} = \sum_{X=1}^{N} D_{k,k+1,X}\, C_1 \quad (6)$$

$D_{k,k+1,X}$ represents the distance between centroids of department 'X' (ranges from 1…N) in period k and k+1.
C_1 = Cost of moving Department X from k to k+1
Thus, the total cost of material handling for the entire period is given by:

$$Z = M + F + V \quad (7)$$

Case Study

For demonstrating the development of the dynamic from-between chart a case study of eight products, nine departments, and 20 periods is used. For this case study all departments are considered to be equal sized (40 x 50). Equations for product Demand is as follows:

$$f(t)_a = -0.136t^4 + 6.6t^3 - 102.38t^2 + 48.4t + 73.7 \quad (8)$$

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$$f(t)_h = -0.077t^4 + 2.9t^3 - 30.2t^2 + 132.9t + 74.93 \quad (9)$$

Table1: Process Sequence

A	1--3--5--7--8--9--2
B	2--4--6--7--1--9
C	4--7--8--2--5--6
D	6--9--3--2--1--4--8
E	8--6--4--1--3--2
F	1--6--7--9--2--4--3
G	2--5--7--6--1--3--4
H	3--6--7--8--1

Based on the product demand and the process sequence (Table 1), a plot of the dynamic from-to charts is developed (Figure 1). Currently, the redesign points are clustered as groups and the first redesign point of each cluster is used for redesign analysis. A recursive genetic algorithm is used to determine the best layout for each period.

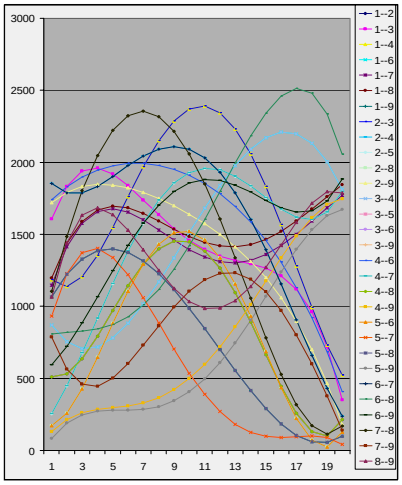

Figure 1. Dynamic From-To Chart

The cost associated with each approach is shown in Table 2. Based on the case study conducted, it is revealed that the dynamic from-between chart approach to select redesign points yields improved solutions compared to the traditional approaches.

Table 2: Comparison of Costs

	Forward Approach Proposed	Backward Approach Proposed	Redesign at every 4 quarters	Single Optimal Layout for 20 periods
Total Cost	329339043	329283924	329442067	338542522
Savings	9203479	9258598	9100455	

3. Conclusions

This paper has presented a new approach to the solution of dynamic facility design problems. The approach models the product demand function as a continuous one and uses the information to develop a dynamic from-between chart. The relative changes in the values of from-between chart are utilized to determine the redesign points. Once the redesign points are determined a forward GA approach is utilized to establish the optimal designs for each redesign period. Based on the case study, it is revealed that the proposed approach is superior to other existing approaches. Future research involves developing an algorithmic approach to the selection of redesign points. We are also investigating methods by which the impact of material-handling devices on the possible redesign of layouts can be determined.

4. Reference

[1] Tompkins, J.A. and White, J.A., Bozer, Y., Z., Tanchoco, J., M., A., 2003, Facilities Planning, third edition (New York: Wiley).