Integration and Optimization of Facility Design Considering Replacement Analysis

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Abstract

Objective: Facilities allocation means placing the facility on a specified plan of land keeping in mind the dealers the clients and other aspects. Now facility allocation involves facility structure plan, layout plan and the material organization plan various research work related to facility organization have been published but they are not the latest, and neither are they related to varied aspects. So the main objective of this research is the integration of facility design and replacement analysis. Method: The research study presented here highlights the after effects of application of algorithm on the layout design and its function. Replacement analysis has been kept as the basis of the new flexible layout design system. This paper has outlined the overall development, major algorithms are described in detail and this paper has also detailed the computer based system. This paper also highlights the varied approach of incorporating flexibility in the designs of the layout. Findings: The developed algorithm, computer based system and flexibility in the design of the layout is highly useful for the researchers and designers. Because while designing a layout, it is necessary to consider the replacement aspect and evaluation aspect, so that the costs handling stays low and replacement in the future remains possible. Application: This research is useful in minimizing the overall cost of material handling and thus gaining best flow pattern.

Keywords: Facility Planning, Optimization Methods, Plant Layout, Replacement Analysis

1. Introduction

In production industry key to competition, sure lays in the fact that the present production system can be reconstructed. In today economical manufacturing scenario, it is necessary to keep one updated with the new facility systems. In near future the production process must be easy to reconfigure so that customized stuff may be produced cost-effectively.

Various researches have been done in the area but finding the best plan configuration is still a problem.

2. Facility-Design

The plan, the layout, the population capacity, tools, organization-movement, or venture are all part of a facility plan. At the same time, how to place the tools, situate or allocate them, how to minimize the assemble time, maximize the equipped arrangement flexibility, maximize productivity in synch with the production schedules are the entire factors determined by a facility plan.

In production system there are three main types of layout; product, process and group-tech layout. The main
The difference between them lies in the distinctiveness of their operations that is quantity and diversity. Today’s market scenario needs to gratify all the queries in which are mainly focused upon-increasing the variety, the change in the class of the product and most importantly the on time-delivery of the product. Now these conditions are true of global-markets also.

In production systems, the three main types of layout are product layout, process layout, and group technology layout, which is again subdivided into flow line, cell, and centre. Tompkins says that, the difference among these types of layout is made based on method distinctiveness such as manufacturing quantity and product diversity. According to Hessen product layout (flow shop) is associated with high volume production and low product diversity, while process layout (job shop) is associated with low-volume production and high product diversity.

As per current aggressive market, production trade has to gratify additional varied uncertainty from the market, such as amplifying the product varieties, escalating class and specific to the deliverance time. The global challenge also involves a bigger diversity of kinds and deviations in vast total product. Zuhdi says that manufacturing companies require being knowledge-intensive and extremely artistic to build up fresh products. To continue competitive, advancement the procedure and accepting information knowledge are also the face up to small and average industries. Judgment creation for any improvement and detailed method or reconfiguring the entire scheme as a answer to market order is a significant movement which can force on the economical feature of the business.

### 3. Algorithm for Flexibility in Layout Design

#### 3.1 Introduction

Algorithm for flexibility in layout design is detailed in this section. This algorithm considers the material flow as input data then channelizes the layout and reschedule the flows. This is done so that the transportation cost is reduced. So the main function of algorithm is to reduce the transportation costs there by reducing the total material flow. If there is any unexpected material flow, it can be kept in check by this algorithm. This algorithm thus provides various profits- channelizing the layout will provide for re-structure or re-schedule and re-schedule will further provide for reduction in total handling cost of the material.

#### 3.1.1 Problem Statement and Modelling

Now the difficulty arising in the process plant for optimizing the total material handling cost gives many possible future material flows. The material flows can have the different cost per unit distance. The final equation is as follows:

$$\text{Minimum } T = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} d_{ij} c_{ij}$$

Where:

- $f_{ij}$ = frequency/quantity of flow.
- $c_{ij}$ = cost to flow one unit load per unit distance between two machines.
- $d_{ij}$ = distance amid machine $i$ and $j$.

Considering the cost $c_{ij}$ remain steady, the aim would be reduced to minimizing the total distance travelled for the parts.

#### 3.1.2 Example of Three Machine Layout

There are six possibilities for three machine layout that is given below in Table 1:

|   | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 2 | 3 |
| 2 | 1 | 3 |
| 2 | 3 | 1 |
| 3 | 1 | 2 |
| 3 | 2 | 1 |

Below is flow matrix and distance matrix considering “c” as a unit cost in Table 2.

|   | 1 | 2 | 3 |
|---|---|---|---|
| 1 | $f_{12}d_{12} + f_{13}d_{13} + f_{21}d_{12} + f_{23}d_{23} + f_{31}d_{13} + f_{32}d_{23}$ |
| 2 | $f_{13}d_{12} + f_{12}d_{13} + f_{31}d_{13} + f_{32}d_{23} + f_{21}d_{13} + f_{23}d_{23}$ |
| 2 | $f_{21}d_{12} + f_{23}d_{13} + f_{12}d_{13} + f_{31}d_{12} + f_{32}d_{23} + f_{13}d_{23}$ |
| 3 | $f_{23}d_{12} + f_{21}d_{13} + f_{32}d_{23} + f_{31}d_{12} + f_{12}d_{13} + f_{13}d_{23}$ |
| 3 | $f_{31}d_{12} + f_{32}d_{13} + f_{13}d_{12} + f_{12}d_{13} + f_{21}d_{23}$ |
| 3 | $f_{32}d_{12} + f_{31}d_{13} + f_{23}d_{12} + f_{21}d_{23} + f_{13}d_{12} + f_{12}d_{23}$ |
Table 3. Flow and distance matrix of three machine layout

| fij | 1  | 2  | 3  | dij | 1  | 2  | 3  |
|-----|----|----|----|-----|----|----|----|
| 1   | -  | 2  | 4  | 1   | -  | 1  | 3  |
| 2   | 6  | -  | 3  | 2   | 1  | -  | 2  |
| 3   | 5  | 1  | -  | 3   | 3  | 2  | -  |

Minimum \( T = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} d_{ij} c_{ij} \)

Table 4. Transportation cost for three machine layout

| Layout | 1 | 2 | 3 | T  |
|--------|---|---|---|----|
| 1      | 2 | 3 | 38|
| 1      | 3 | 2 | 37|
| 2      | 1 | 3 | 43|
| 2      | 3 | 1 | 43|
| 3      | 1 | 2 | 47|
| 3      | 2 | 1 | 46|

Here we can see that the layout 1-3-2 is most optimum layout.

4. Replacement Model

Replacement model falls in to two categories depending upon the tool’s existing model. The categories can be – whether the tool deteriorate or exhaust due to prolong usage or overuse or the tool fails quickly without warning. Now for the tools that exhaust quickly the trouble is to manage the ratio of wielding charges of new tools maintaining potency on the old/cost due to the loss of potential. There have been various constructions using simple assumptions on the difficulty still no universal answer has been reached.

A separate problem asks for the replacement of the items- such as radio, night/light bulbs etc. which does not drop with time but suddenly fails. The difficulty here is which item to be replaced and when to pave them in assembly. The focus here is to minimize the cost of the replacement and the cost connected with the failure of the equipment.

Another inevitable condition where the replacement becomes the only option is the condition which arises due to superannuation. The property of being out of date and not current is not the reason behind the replacement, but because, not only the modern tools have set higher benchmarks but also have performed accordingly.

Most often the cost of renovation and maintenance is so high that it seems cheaper to replace the older ones with new ones. Since these two kinds of costs are inclined to rise with time, they are grouped to analyze a problem.  

Replacement of part that decline 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 \( = \int f(t).dt, (0 \text{ to } n) \)

Total cost incurred during \( n \) year \( T(n) = C - S + \int f(t).dt, (0 \text{ to } n) \)

Average annual cost incurred on the item \( T_{avg} = 1/n [C - S + \int f(t).dt, (0 \text{ to } n)] \)

Now we shall find that value of \( n \) for which \( T_{avg} \) is minimum. Differentiating previous equation w.r.t. \( n \), we get \( d/dn (T_{avg}) = -1/n^2 \cdot (C-S) - 1/n^2 \int f(t).dt, (0 \text{ to } n) + 1/n.f(n) \).

\( d/dn (T_{avg}) = 0 \), we have \( f(n) = T_{avg} = 1/n [C - S + \int f(t).dt, (0 \text{ to } n)] \)

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 separate variable

In this case, the total cost incurred during \( n \) year, \( T(n) = C - S + \int f(t).dt, (0 \text{ to } n) \)
Average annual cost incurred on the item,
\[ f (n) = \frac{1}{n} [C - S + \int f(t).dt, (0 \text{ to } n)] \]

'\text{n}' is optimal at the east average annual cost.

For example:
The maintenance cost and resale value per year of a machine whose purchase price is Rs. 7000 is given below in Table 5.

| Year | Maintenance cost in Rs. | Resale value |
|------|-------------------------|--------------|
| 1    | 900                     | 400          |
| 2    | 1200                    | 2000         |
| 3    | 1600                    | 1200         |
| 4    | 2100                    | 600          |
| 5    | 2800                    | 500          |
| 6    | 3700                    | 400          |
| 7    | 4700                    | 400          |
| 8    | 5900                    | 400          |

Table 5: Maintenance cost and resale value

When should the machine be replaced?
Capital cost \( C = 7000 \) Rs. Let it be profitable to replace the machine after \( \text{n} \) year. Then \( \text{n} \) should be determined by the minimum value of \( T_{avg} \), values of \( T_{avg} \) for various years are computed in table.

We observed from the Table 6 that average annual cost is minimum (Rs. 3020) in the 5\(^{th} \) year. Hence the machine should be replaced at the end of 5\(^{th} \) year of service.

Table 6: Replacement Analysis

| Purchase Price \( \text{©} = 7000 \) |
|---|---|---|---|---|---|---|---|
| 1  | 2  | 3  | 4  | 5  | 6  | 7  | Average |
| N  | S  | c-s| f(t)| F(t)| (3+5)| | |
| 1  | 4000| 3000| 900 | 900 | 3900| 3900 |
| 2  | 2000| 5000| 1200| 2100| 7100| 3550 |
| 3  | 1200| 5800| 1600| 3700| 9500| 3167 |
| 4  | 600 | 6400| 2100| 5800| 12200| 3050 |
| 5  | 500 | 6500| 2800| 8600| 15100| 3020 |
| 6  | 400 | 6600| 3700| 12300| 18900| 3150 |
| 7  | 400 | 6600| 4700| 17000| 23600| 3371 |
| 8  | 400 | 6600| 5900| 22900| 29500| 3688 |

Where:
\( n = \text{Year of Service} \)
\( S = \text{Resale Value} \)
\( f(t) = \text{Annual Operating /Maintenance Cost} \)

5. Result

Table 7: Result

| 1 | Initialization | Input data: Maintenance Cost of each machine, Resale Value of each machine, Flow matrix and Distance matrix. |
|---|---|---|
| 2 | Replacement analysis | It is found that machine 3 should be replaced at 2019. |
| 3 | Calculation of Transporting Cost | It is found that arrangement 1-3-2 is optimum flow path. |
| 4 | Result | Found the optimum and fresh layout of 1-3-2 |
| 5 | Benefit | We can save the shifting cost. Best and economic flow pattern is obtained. Hence overall cost of product will be decreased. |

6. Conclusions and Future Work

The explicated attributes of algorithms and computer based system explained in this study, exemplify the importance of the flexibility for the layout design. The study performed in this research with all type of illustrations along with the highly-developed computer based program is not only highly useful for the researchers and designers but also exceptionally sort after for flexible layout design.

When a layout is designed two things are always kept in mind: Information of the material flow and Replacement and Evaluation perspective.

With the help of replacement analysis the competitive edge of the industry could be maintained by analyzing the total material handling costs and flexibility regarding the disturbance in future. It will also help to make optimum facility layout and save the shifting costs there by obtaining the best and economical flow pattern. Hence overall cost is minimized.

This approach is method based. In a functioning plant many factors are required to be considered. Like aisle-arrangement, office requirements, personnel requirements- such as-lockers, restrooms, food services, health services etc. This includes the material handling costs as well.

In future computer- aided drawing tools should be more sort-after because not only they minimize the time consumed to create a layout but they will also help the designer to modify the layout created by algorithm.
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