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Optimum Facility Layout by the Application of ABC Control

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Abstract: ***In this study, we are focusing on different types of problems which are related to facility planning and layout design for different types of production areas. The main problems which are related to location of facilities which also affects the system performance such as distribution of man, material and machine in a plant or a factory and their optimization technique while using of mathematical models, their solutions and application related to whole problems is presented. For solving this type of problems, intelligent techniques such as expert systems, fuzzy logic, neutral networks and ABC control have been used. In this paper the recent analysis on facility layout is incorporated and facility layout problem is surveyed. Many intelligent techniques and conventional algorithms for solving FLP are presented. The effect of workflow obstruction is a major concern in facility layout design. Yet, despite the wide amount of research conducted on the facility layout problem, but there is need of effective layout design and effective maintenance plan for the wide range of machine working in the plant. This paper uses ABC concept for effective maintenance and examines the impact of workflow obstruction considerations on facility layout analyses. Linear and nonlinear integer programming formulations of the problem are presented. The structural properties of the resulting formulations, as applied to facility design, are investigated. Finally, a multi-objective approach to facility layout design is presented, incorporating the usual distance-based objective with that of workflow interference.***

Keywords: Facility Planning, ABC control, Material handling Optimization method.

1. Introduction

Future manufacturing system needs to be dynamically reconfigurable to produce customized products in small batch with fast turn-around times in cost-efficient manner. The capability to reconfigure an existing manufacturing system is a key factor to maintain competitiveness in manufacturing business environment. Suggested that in order to be successful in today's competitive manufacturing environment, managers have to look for new approaches to facilities planning.

A factory or a plant is the manufacturing facility of a company. A warehouse is the storage facility of a manufacturing or a distribution Company. By proper planning of these facilities would definitely reduce the total cost of operation and maintenance. Facility setup without proper planning causes following events:
1. Sell of the facility to other companies.
2. Close down the operations.
3. Relocate facility to a new location.

Wrong selection of the family may lead to a failure of the complete project. By considering two primary parameters cost and distance many models have been made which helped to take decision in this field. The readers who want to share his idea to learn about facility location models are referred to the works of Francis and White (1974) [1]. , Handler and Mirchandani (1979) [2]. , Love,Morris, and Wesolowsky (1988) [3]., Drezner and Hamacher (2002) [4]. , Nickel and Puerto (2005) [5]. , Church and Murray (2009) [6] and Farahani and Hekmatfar (2009) [7]. Simulation studies are used to measure the advantage and performance of given layouts (Aleisa & Lin, 2005)[8]. Unfortunately, layout problems are known to be complex and are generally NPHard (Garey & Johnson, 1979) [9]. Finally, a tremendous amount of research has been carried out in this area during the last decades. A few surveys have been published to review the different trends and research directions in this area. However, these surveys are either not recent (Hassan, 1994 [10]; Kusiak & Heragu, 1987 [11]; Levary & Kalchik, 1985) [12], or focus on a very specific aspect of layout design, such as loop layouts (Asef-Vaziri & Laporte, 2005) [13], dynamic problems (Balakrishnan & Cheng, 1998) [14] and design through evolutionary approaches (Pierreval, Caux, Paris, & Viguier, 2003) [15]. Benjaafar, Heragu, and Irani (2002) [16] conducted a prospective analysis and given their suggestion in research directions. The objective of layout planning is classified into two categories: a) Quantitative type, b) Qualitative type. Quantitative is related to material handling cost and qualitative type is related to distance closeness rating. Objective is to minimize the material handling cost and maximize total distance closeness rating. The covering model which is most popular model and critical predefined number is called coverage distance or coverage radius (Fallah, NaimiSadigh, & Aslanzadeh, 2009) [17].Many problems like selection of location for police station, hospital, school can be easily formulated as covering problems. (Francis & White, 1974) [1]. Schilling, Jayaraman, and Barkhi (1993) [18] showed the literature review on covering problems in facility location. Schilling et al. (1993) [18] classify models which use the concept of covering in two categories: (1) Set Covering Problem (SCP) where coverage is required and (2) Maximal Covering Location Problem (MCLP) where coverage is optimized. Owen and Daskin (1998) [19] have shown overview on facility location

considering dynamic characteristics. Conforti, Cornuéjols, Kapoor, and VuŠkovic´ (2001) [20] study results and also problems on perfect, ideal and balanced metrics which are related to set packing and set covering problem. Berman Drezner and Krass (2010b) [21] had shown their overview of covering model concentrate on three areas:
(i) gradual covering model,
(ii) cooperative covering model and
(iii) variable radius model.

Complex computational tools are needed for multi-criteria ABC classification. Flores et al. [24] provide a matrix-based methodology. A joint criteria matrix is developed in the case of two criteria. However, the methodology is relatively difficult to use when more criteria have to be considered. Several multiple criteria decision-making (MCDM) tools have also been employed for the purpose. Cohen and Ernst [24] and Ernst and Cohen [25] have used cluster analysis to group similar items. The analytic hierarchy process (AHP) [27] has been employed in many MCIC studies [23,26–27]. When AHP is used, the general idea is to derive a single scalar measure of importance of inventory items by subjectively rating the criteria and/or the inventory items [22]. The single most important issue associated with AHP-based studies is the subjectivity involved in the analysis. Heuristic approaches based on artificial intelligence, such as genetic algorithms and artificial neural networks [22], have also been applied to address the MCIC problem.

2. ABC Control

It contemplates to classify all the machines in to three categories based on their uses value. uses value includes the operation cost on machine and the maintenance cost incorporated with the machine. Machines of high uses value but small in numbers are classified as ‘A’ machines and would be under strict control of top level management. ‘C’ machines are large in number but require little capital and would be under simple control. Machines of moderate value and size are classified as ‘B’ machines and would attract reasonable attention of the middle level management. ‘ABC’ analysis (always better control analysis) is also known as control by important sans exception and proportional value analysis.
It has been found that normal working machines in most organization show the following distribution patterns:
A : 5 to 10 % of the total number of machines accounting for 70 to 80% of the annual uses value,
B : 10 to 20% accounting for about 15 to 20% of the annual uses value, and
C : 70 to 80% of the number of machines accounting for 5 to 15% of the annual uses value

Under ABC analysis, an organization would devote much time and effort in the control of ’A’ machines. extra care will be taken for determining the operation condition and maintenance requirement etc. of the ‘A’ machines whereas so much control may not be exercised on ‘C’ machines. ‘A’ machines have high operation costs and should, therefore, be optimally used and location of working place must be effective. Fixed-interval maintenance system may be used for these machines. ’C’ machines require very little capital and hence have low maintenance cost and should be used in bigger lots so that there are fewer maintenance and hence lower acquisition cost and so this type machine placed by considering optimum use of plant area available. A fixed-order maintenance system may be used for such machines. ‘B’ machines are usually placed under statistical control and attract periodic maintenance of machine.

3. Layout Formulation

The characteristics of any manufacturing unit either it is related to static or dynamic, there are different types of mathematical model is formulated. Such models can based on different principles, which consist in graph theory Proth, 1992 [29] or neural network (Tsuchiya, Bharitkar, & Takefuji,1996 [30]. These models are used as a suggestive solutions to the layout problems which most generally used by the researchers consider as optimization problems, with either single or multiple objectives. Depending on discrete or continuous, the formulations found in the literature can lead to Quadratic Assignment Problems (QAP) or Mixed Integer Programming’s (MIP).

By considering the plant as a discrete, the whole plant is divided into small rectangular area which is called as a facility (Fruggiero, Lambiase, & Negri, 2006) [31]. If facilities have unequal areas, they can occupy different blocks (Wang, Hu, & Ku, 2005) [32].

A formulation, which is related to determining the relative locations of facilities so as to minimize the total material handling cost, is as follows (Balakrishnan, Cheng, & Wong, 2003) [33]:

$$\text{Minimum } T = \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} FikDjlXijXkl$$

$$\sum_{i=1}^{n} Xij = 1 \quad j = 1,2,3 \ldots\ldots\ldots\ldots N$$

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where N is the number of facilities in the layout, fik the flow cost from facility i to k, djl the distance from location j to l and Xij the 0, 1 variable for locating facility i at location j.

All facilities can be placed anywhere within the planar site and must not overlap each other.

The facilities can be located in the plant site are located either by their centroid coordinates (xi,yi), half length li and half width wi or by the coordinates of left corner, length Li and width Wi of the facility. The distance between two facilities can be, expressed in the rectilinear norm (Chwif et al., 1998) [34]:

$$Dij\left((Xi,Yi), (Xj, Yj) \right) = \left| Xi - Xj \right| + \left| Yi - Yj \right|$$

The first mathematical model which is related to covering problems was developed by Toregas, Swain, ReVelle, and Bergman (1971) [35]. They considered modeling the location of emergency service facilities as follows:
i: the index of demand nodes,
j: the index of facilities,

Ni: the set of potential locations within S so that (Ni = jdij<=S)
xj: a binary decision variable relate whether the facility located at point j or not,
dij: the distance between demand node i and facility j, and
S: a maximum acceptable service distance.

The model is as follows:

$$\text{Min} = \sum_{j=1}^{n} X_j$$

S.T

$$\sum_{J=ni} X_j \geq 1 \ \forall\ i=1\ 2\ 3\ldots\ldots\ldots\ldots m$$

$$X_j \in (0,1) \quad j= 1\ 2\ 3\ldots\ldots\ldots\ldots n$$

The mathematical formulation for set covering problems tries to minimize location cost satisfying a specified level of coverage is as follows:
i: the index of demand nodes,
j: the index of facilities
xj: a binary decision variable indicating whether the facility located at point j or not,
S: the maximum acceptable service distance,
cj: the fixed cost of locating facility at node j and
aij: a binary parameter is 1 if distance from candidate place j to the existing facility (customer) i is not greater than S.

The model is as follows:

$$\text{Min} = \sum_{j=1}^{n} C_jX_j$$

$$\sum_{J=1}^{n} a_{ij}.X_j \geq 1 \ \forall\ i=1\ 2\ 3\ldots\ldots\ldots\ldots m$$

$$X_j \in (0,1) \quad j= 1\ 2\ 3\ldots\ldots\ldots\ldots n$$

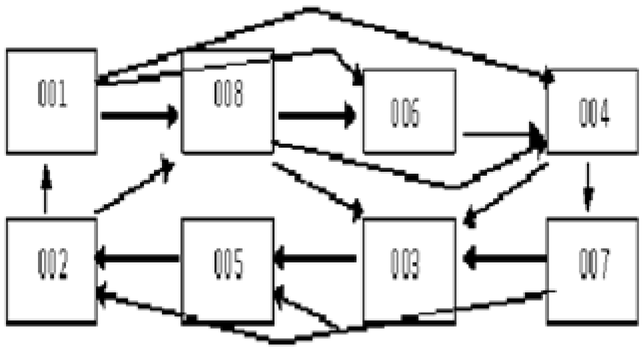

Figure 1: Minimizing distance traveled (by flow and distance matrics)

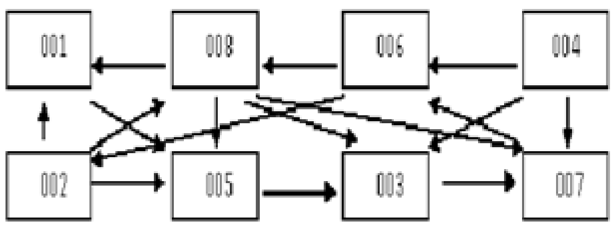

Figure 2: Minimizing work flow interference

4. Conclusion

The ABC analysis is a straight forward approach that assist plant analyst or a designer in achieving cost effective management while considering both qualitative and quantitative aspect in facility layout problems such as office layout, shop floor and workshops etc.

While considering ABC classification and the effect of workflow interference smoother material flow occurs among the departments which make the operator easy to observe, maintain and control. Different mathematical models are developed and formulated which minimize material handling cost and maximize closeness rating as well as modified concurrent design layout are developed which determines the location of I/O points with multi objective approach.

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