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Solving the design of distributed layout problem using forecast windows: A hybrid algorithm approach

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ABSTRACT

In today's competitive environment, manufacturing facilities have to be more responsive to the frequent changes in product mix and demand by realigning their organizational structure for minimizing material handling cost. However, manufacturing firms are reluctant to modify the layout as it leads to operation disruption and excess rearrangement cost. In this paper, we present an alternative approach for designing a multi-period layout (i.e., distributed layout) that maintains a tradeoff between re-layout cost and cost of excess material handling. Obtaining an optimal solution to distributed layout problem is generally a difficult task, owing to larger size of quadratic assignment problem. In order to overcome the aforementioned drawback, a meta-heuristic, named 'CSO-DLP' (Clonal Symbiotic Operated-Distributed Layout Planning) is developed for designing a distributed layout that jointly determines the arrangement of department and flow allocation among them. It inherits its trait from Symbiotic algorithm and Clonal algorithm. In addition to these; the concept of 'forecast window' is used, which evaluates the layout for varying number of periods at a given time. The proposed meta-heuristic is applied on a benchmark dataset and the effect of system parameters, such as rearrangement cost, department disintegration, and duplication are investigated and benchmarked in this paper.

1. Introduction

Today manufacturing industries are experiencing a remarkable challenge from consumer market to ensure high productivity in less time and lower operating cost. The industries are interested in improving their competitive edge in global market place by realigning their organizational structure and their competitive strategies. This quest for better manufacturing efficiency in firms has changed the dynamics of plant layout. In addition, the design of plant layout varies from period to period in an environment, where demand variability is high and product variety is low [13]. In such environment, there is a need to design a layout for each period that compensates the rearrangement cost with efficient material flow in each period. Keeping in mind the intricacies involved in the aforementioned issues, in this article we present a multi-period distributed layout model for jointly determining the arrangement of departments and flow among them. In a distributed layout, departments are disintegrated into sub-departments and distributed throughout the plant flow. A novel metaheuristic incorporating the features of *Symbiotic algorithm* and *Clonal algorithm* has been proposed for designing the aforementioned distributed layout.

The layout design problem is encountered in diverse areas of everyday operations such as industrial organization, hospital management, electronic manufacturing etc. It deals with the efficient arrangement of facilities that contributes to attain the desired goal of profitability. The basic requirement for the analysis of the system is: group of departments, material flow among departments and cost of per unit flow per unit distance. The cost of material flow has been estimated to comprise between 30 and 70% of the operating expenses [22]. Therefore, the primary objective of layout problem is to minimize the sum of material handling cost among departments.

Most of the researchers have proposed their methodology with an objective to minimize the production cost by minimizing the material handling cost among the facilities. Such traditional methodologies have assumed the flow to be a constant quantity that makes the problem static one. Due to the dynamic nature of business, the flow may vary with time for certain reasons, such as

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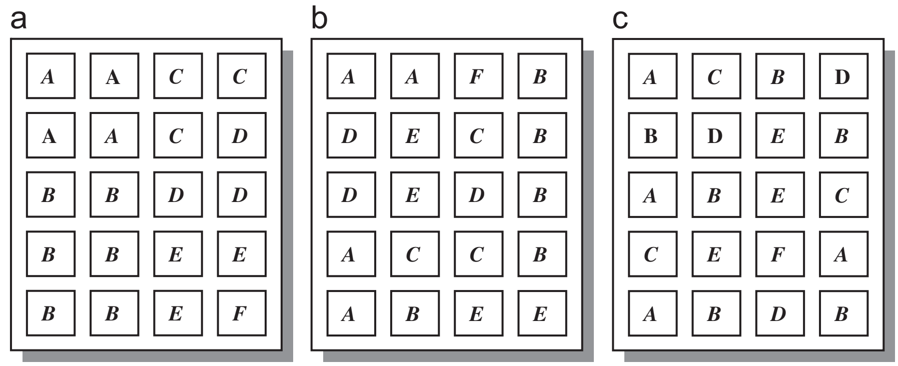

Fig. 1. Layouts with varying degree of distribution: (a) functional layout; (b) partially distributed layout (c) fully distributed layout.

change in demand, mechanical failure, environmental changes etc. Since layout planning is a long-term and costly proposition, mostly the firms adopt multi-period layout and disregard the change in flow. In such approach, the relative arrangement of departments is determined on the basis of aggregate flow cost performed by the addition of flows of each period.

However, this approach is not justified in a situation when the rearrangement cost is negligible. In such circumstances, modification of the present layout can be suggested without any prior planning [5]. On the other hand, if the rearrangement cost is extremely high, we use the same layout for most of the periods. It is argued that in such situations the option pertaining to rearrange the layout is ignored. Due to the aforementioned intricacies, we present a procedure to design a distributed layout through disintegration and dispersion of existing functional department to hedge against the changes.

The concept of distributed layout is given by Montreuil et al. [18]. In a distributed layout, departments are disintegrated into sub-departments and dispersed in non-adjoining location. The dispersion of sub-departments of same type in different area of plant facilitates the flow pattern for long term without any rearrangement. Fig. 1 represents the schematic structure of layout with varying degree of distribution. The features of distributed layout are:

- Reduction of the distance between departments.
- Minimization of material handling cost.

We also advocate that the key issue for designing a distributed layout is not only the optimal arrangement of departments, but also the flow allocation among sub-departments. From literature, it has been found that methods and algorithms are not very interactive and need much more processing time for getting optimal layout design with best flow allocation. The computational complexities related to such approaches motivate some researchers for treating the layout problem heuristically. It is also known that, although heuristic are generally quick, they are prone to become entrapped in local optimal and do not always provide true optimal solution [24].

These shortcomings have led the author to develop a model that incorporates optimal and sub-optimal techniques for designing a layout. At the heart of the proposed model is the concept of ‘forecast window’, proposed by Urban [25]. The motivation is to develop a model for multiple periods based on the trade off between excess material handling cost for a layout without any modification and rearrangement cost. In order to generate an optimal layout enabling the aforementioned heuristic, a new kind of meta-heuristic, entitled as *Clonal symbiotic operated-distributed layout planning* (CSO-DLP) is proposed in this paper to solve this complex problem for optimal/sub-optimal solution. To prove the efficacy of proposed model, experiments are performed on a known data set considering the multiple locations of each department.

1.1. Literature review

A significant amount of literature exists in the area of layout design problem to determine the arrangement of departments on the basis of material handling cost or some qualitative interrelationship among departments. However majority of work is performed for *static facility layout problem* (SFPL) considering the cost or rating for single period. A comprehensive review on static layout can be seen in [14].

Such analysis would not be suitable in an environment, where product demand and material handling cost vary from period to period. In this environment, there is a need to design a layout based on multi-period time horizon. For such conditions, plant may adopt a dynamic layout that can be modified in one or more periods. However, there is limited research in the body of literature dealing with *dynamic facility layout problem* (DFLP) [13,20,21]. Rosenblatt [20] proposed a heuristic for modeling the DFLP by computing lower and upper bounds on the selection of layout. Rosenblatt did not conduct any experiment using large problems. Urban [26] pointed out this drawback and presented a heuristic based on steepest descent pair-wise interchange procedure to avoid the dimensionality problem. Since then various deterministic and stochastic procedure models have been proposed to improve the Rosenblatt [20] original dynamic problem model.

A review of literature on the dynamic facility layout problem can be found in [5]. A Hybrid GA [6], SA algorithm [7], Hybrid Ant systems [16], SA algorithm based Heuristics SA I and SA II [17] have been proposed to solve the DFLP. Their performances have been compared with those of other methods and heuristics that have been previously used to solve the DFLP.

The remainder of this section is devoted to distributed layout problem. Montreuil et al. [18] gave the concept of distributed layout where a department is disintegrated into sub-departments and dispersed in non-adjoining locations. Benjaafar and Sheikhzadeh [8] proposed a model for minimizing the total material handling cost by effectively arranging the departments and allocating efficient flow among them. An intensive comparison on the performance of distributed layout with functional and cellular layout was carried by Askin et al. [3]. Recently, Lahmar and Benjaafar (2005) proposed a decomposition based heuristic with an objective to balance re-layout costs between periods with material flow efficiency within each period. This approach is based on an iterative procedure in which solution is obtained by iteratively solving the layout problem with fixed flow followed by flow allocation with fixed layout. This isolated approach does not guaranteed optimality, whereas it satisfies the necessary conditions for optimality. To resolve this problem, a meta-heuristic has been developed by incorporating the features of Symbiotic algorithm and Clonal algorithm. By including these features the proposed model appears robust and close to the