



Dynamic facility layout problem in footwear industry



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ABSTRACT

Dynamic facility layout problem (DFLP) deals with the arrangement of machines in a site as to minimize the sum of materials handling and re-layout costs by considering multi periods. The DFLP studies in the literature provide several different algorithms and utilize the well known test problems to assess their performance. However, real life applications are overlooked. The industries such as footwear and clothing are prone to seasonal demand changes. Therefore, time horizons and layout/re-layout of the machines within the facility should be studied carefully. This study considers a footwear facility and several scenarios are generated by using the real life data. A clonal selection based algorithm is proposed to solve the real life DFLP. The performance of the algorithm, further the effect of time periods on solution quality and applicability of the results are tested and promising results are obtained.

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1. Introduction

Main aim of most production facilities is both to minimize the manufacturing costs and to increase the variety and quality of their products. This necessity endorses the importance of flexibility, reconfiguration, and responsiveness. Common features of flexible, agile, and lean manufacturing is called as dynamism. In a manufacturing environment, batch sizes, routes, and unit handling costs usually depend on the technology and any change in the system may be costly. The total material handling costs within a facility are mainly affected by demand that usually depends on consumer, technological parameters, and facility layout. The dynamic variability against changing demand scenarios can be reduced with limited changes in the layouts to keep material handling costs at their minimum [1].

The facility layout problems are crucial since the material handling costs are directly related with the location of machines in the facility. Dynamic facility models can provide more effective results to meet the requirements of the changing environments by considering multi periods rather than static layouts and named as DFLP. The studies in the literature related with DFLP focus on the theory of the problem, provide exact and heuristic models and utilize the test problems introduced in the pioneering studies such as, Rosenblatt [2], Conway and Venkataraman [3], Balakrishnan and Cheng [4]. However, up to the best knowledge, the DFLP in real life manufacturing systems are not considered. Therefore, this study aims

to model a real life layout problem where multi periods need to be considered and fill the gap between the theory and application of DFLP.

In a static layout, a single period is considered and main aim is to locate the machines so that total materials handling cost, resulting from the number of flows between machines, is minimized. However, in application, due to some demand fluctuations between consecutive periods, minor changes in the machine locations may result with notable benefits. The decisions to relocate the machines are influenced by the trade-off between re-layout and superfluous handling costs. Usually two extreme cases may emerge. One is the case where the re-layout costs, resulting from relocation, are very high and managers may not be eager to move the machines. On the contrary, the re-layout costs may be relatively low compared to the handling costs and a relocation to react the new conditions is preferred. DFLP stands between these two cases.

This study focuses on the flexible, reconfigurable, and agile manufacturing environments where the demand is affected by fashion and season such as in clothing and footwear industries. The nature of demand and also relatively low re-layout costs of machines and or workstations used in footwear industry urges to employ dynamic layout models.

The footwear industry manufactures footwear for men, women, and children. The products of this industry can be grouped basically as slipper, boot (industrial, security, and military), child, women, men shoes, and sport shoes (the monoblock products, cast from rubber and/or plastic are excluded). These organizations are inter-related with other industries such as leather, textile, metal, and plastics. Consumers require new products with better comfort and design. Consequently, the competition is becoming stronger

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in current global market. Therefore, flexibility and promptness in designing new products are key factors for the medium and long-term survival and success of the footwear industry.

The studies in literature concerning footwear industry mainly focus on manufacturing and automation issues, possible health problems, and also the cases for different countries. Development and operation of an integrated design and manufacture system for “shoe lasts” have been discussed because the shoe last is the most important component in the entire footwear fabrication process [5]. Kochan [6] provided robotic solutions for a variety of shoe making processes. Costa and Ferreira [7] solved a flexible flow line scheduling problem in the footwear industry. Kim et al. [8] drew attention to global competition and proposed a virtual global manufacturing system in a shoe company. Nemec and Zlajpah [9] described a robotic cell for finishing operations in a custom shoe production plant. Barnett et al. [10] discussed the footwear industry in Europe and then proposed a distributed scheduling approach to provide the required autonomy in decision-making and flexibility in job sequencing at the departmental level to deal with the complexity of planning a large number of small batch production orders. Fornasiero et al. [11] introduced a new tool that has been developed by a service provider to the footwear industry to support shoe producers in managing costs and orders automatically through a web application. Jatta et al. [12] described the design and implementation of an innovative robotic cell for roughing and cementing of shoe uppers. Pujawan [13] presented a case study of schedule nervousness based on field observations in a shoe manufacturing company in Indonesia. Chiou et al. [14] discussed Taiwanese footwear manufacturing firms and their competitive advantages. Bertolini et al. [15] analyzed some relevant supply chain management issues for Italian firms. Dietrich et al. [16] noted the importance for enterprises to react quickly to changes in the business environment, presented a service-oriented architecture based approach for mass customization in the shoe industry, and illustrated it with a case study. Suer et al. [17] focused on cell loading and scheduling issues in a shoe manufacturing company. Based on the accessible literature, though its importance, there were no study considering the facility layout problem for footwear industry in multi periods. Therefore, this study adopts DFLP principles and attracts attention to the determination of the number of periods that is crucial for the DFLP. Therefore, several dynamic and static layout scenarios are investigated and the results are discussed based on their total costs and applicability.

The paper is structured as follows: in the following section, structure of DFLP and the solution approaches for is in literature are discussed. Then, the algorithm proposed to solve the problem is introduced in Section 3. Section 4 introduces the case study for the footwear manufacturing facility in concern. The outcomes of different scenarios and their potential application are discussed in the last section.

2. Dynamic facility layout problem

DFLP aims to minimize the sum of handling and re-layout costs by devising an individual layout for each distinctive production period. The mathematical model introduced by Balakrishnan and Cheng [4] is as follows:

$$\text{Min} \sum_{t=2}^T \sum_{i=1}^N \sum_{j=1}^N \sum_{l=1}^N A_{tijl} x_{(t-1)ij} x_{til} + \sum_{t=1}^T \sum_{i=1}^N \sum_{j=1}^N \sum_{k=1}^N \sum_{l=1}^N f_{tik} d_{jl} x_{tij} x_{tkl} \quad (1)$$

s.t

$$\sum_{j=1}^N x_{tij} = 1, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T, \quad (2)$$

$$\sum_{i=1}^N x_{tij} = 1, \quad j = 1, 2, \dots, N, \quad t = 1, 2, \dots, T, \quad (3)$$

$$x_{tij} \in \{0, 1\}, \quad \forall i, j, t \quad (4)$$

where N , number of machines (locations); T , number of periods; f_{tik} , flow at period t between machine i and k ; d_{jl} , distance between locations j and l ; A_{tijl} , fixed cost to relocate machine i from location j to l in period t .

The objective function (1) enables to minimize the sum of re-layout and material handling costs throughout the planning horizon. Constraint (2) states that each department is assigned to a location in each period and (3) guarantees that each location is occupied by a department in each period. The decision variables are kept either at 1 or at 0 by constraint (4).

Re-layout of the machines within the facility may cause some production losses. Dismantling of the machines, preparing new fundamentals, moving the machines to new locations, installation of electricity conveys additional costs, as well. Re-layout may also some indirect costs like production control, loss of time, and training costs. That is why a facility is not reconfigured against each demand change. However, if the potential gain due to the change is large enough, re-layout may be economic and reasonable. In these models, planner is assumed to play a game against nature. There are chance and decision points on the time horizon at this game. At the chance points, nature play (customer changes preferences), a new demand structure occurs. Then, planner makes or does not make a new arrangement on layout at corresponding decision point. This decision heavily depends on the balance between materials handling and re-layout costs. The relocation is made if the re-layout costs are lower than current materials handling costs.

An extended review study for DFLP was provided by Balakrishnan and Cheng [18]. Moslemipour et al. [19] also reviewed intelligent approaches for designing dynamic and robust layouts in flexible manufacturing systems. Dong et al. [20] studied the problem where new machines can be added or old machines can be removed from the plant. Sahin et al. [21] considered the limited budget in DFLP. McKendall and Liu [22] studied new tabu search heuristics for the problem. Pillai et al. [23] proposed a design for robust layout under a dynamic demand environment. Jolai et al. [24] dealt with a multi-objective unequal sized DFLP with pickup/drop-off locations. Ardestani-Jaafari [25] discussed proper formulation of DFLP solutions in Abedzadeh et al. [26] where dynamic flexible bay layout problem formulation with three objectives: minimizing material handling and relayout cost, maximizing adjacency ratio, and minimizing shape ratio difference was discussed. Chen [27] introduced a new data structure for solution representation in hybrid ant colony optimization for large problems. Hosseini-Nasab and Emami [28] proposed a hybrid particle swarm optimisation algorithm to find near-optimal solutions. Emami and Nookabadi [29] introduced a DFLP objective function where each of the cost terms can be given a different importance by the decision makers. Mazinani et al. [30] modelled dynamic flexible bay layout and solved the problem using a genetic algorithm. Samarghandi et al. [31] focused on metaheuristics for fuzzy DFLP. Hosseini et al. [32] proposed a robust and simply structured hybrid technique based on integrating three meta-heuristics: imperialist competitive algorithms, variable neighborhood search, and simulated annealing, to efficiently solve the DFLP. Pourvaziri and Naderi [33] developed an efficient hybrid multi-population genetic algorithm. Ulutas and Islier [34] proposed a clonal selection algorithm (CSA) to solve DFLP. Since CSA was determined to be competitive with other algorithms to solve test problems, its performance on data from real life is studied in this study.

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