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Facility Planning and Associated Problems: A Survey

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ABSTRACT
In this study, we have classified and reviewed different types of problems which are related to facility planning and layout design for different types of manufacturing processes. 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 and neutral networks 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. In our discussion different research direction, general remarks and tendencies have been mentioned
Keywords—Facility Planning, Material handling Optimization method

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. Taha *et al* [76] 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:

- Sell of the facility to other companies.
- Close down the operations.
- 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]. , Francis, McGinnis, and White (1992) [4]. Mirchandani and Francis (1990) [5]. , Daskin (1995) [6]. , Drezner (1995) [7]. , Drezner and Hamacher (2002) [8]. , Nickel and Puerto (2005) [9]. , Church and Murray (2009) [10] and Farahani and Hekmatfar (2009) [11]. Simulation studies are used to measure the advantage and performance of given layouts (Aleisa & Lin, 2005) [12]. Unfortunately, layout problems are known to be complex and are generally NP-Hard (Garey & Johnson, 1979) [13]. 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 [14]; Kusiak & Heragu, 1987 [15]; Levary & Kalchik, 1985) [16], or focus on a very specific aspect of layout design, such as loop layouts (Asef-Vaziri & Laporte, 2005) [17], dynamic problems (Balakrishnan & Cheng, 1998) [18] and design through evolutionary approaches (Pierreval, Caux, Paris, & Viguier, 2003) [19]. Benjaafar, Heragu, and Irani (2002) [20] 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) [21].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) [22] showed the literature review on covering problems in facility location. Schilling et al. (1993) [22] 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) [23] have shown overview on facility location considering dynamic characteristics. Conforti, Cornuéjols, Kapoor, and VuŠkovic´ (2001) [24] 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) [25] had shown their overview of covering model concentrate on three areas: (i) gradual covering model, (ii) cooperative covering model and (iii) variable radius model.

FACILITY PLANNING

Facility planning is concerned with the design, layout, and accommodation of people, machines and activities of a system or enterprise within a physical spatial environment. Furthermore, Meller [51] states that facility layout design determines how to arrange, locate, and distribute the equipment and support services in a manufacturing facility to achieve minimization of overall production time, maximization of operational and arrangement flexibility, maximization of turnover of work-in process (WIP) and maximization of factory output in conformance with production schedules. In manufacturing systems, the three main types of layout are product layout, process layout, and group layout, which is further categorized into flow line, cell, and centre. According to Tompkins [36], the distinction between these types of layout is made based on system characteristics such as production volume and product variety. Product layout (flow shop) is associated with high volume production and low product variety, while process layout (job shop) is associated with low-volume production and high product variety (Fig. 1).

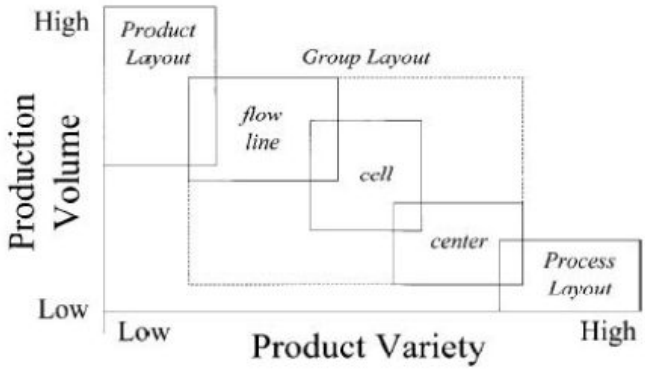


Fig 1.Types of layout

In today's competitive market, manufacturing industries have to satisfy more diverse queries from the market, such as widening the product ranges, increasing quality and precise the delivery time. The international competition also requires a larger variety of types and variants in large volume product. Hassan *et al* [42] suggests that manufacturing companies need to be knowledge-intensive and highly creative to develop new products. To remain competitive, upgrading the process and adopting information technology are also the challenge of small and medium industries. Decision making for either upgrading the specific process or reconfiguring the whole system as a response to market demand is a critical activity which can impact on the economical aspect of the company. Hence, it must be supported by an appropriate analysis tool. According to Hassan, *et al* [42], the simulation method is preferred because of the capability in capturing the dynamics of the complex system. The important of simulation in the era of lean manufacturing is the validation of the design or redesign of a complex manufacturing system before implementation.

LAYOUT PROBLEMS

Facility may be related to machine tool, a manufacturing cell, a machine shop, a department, a warehouse, et (Heragu, 1997) [26]. Koopmans and Beckmann (1957) [27] were among the first to define the problems associated with facility location and given the approach to minimize the cost of transporting materials between them. Meller, Narayanan, and Vance (1999) [28] considered that the facility layout problem consists in finding a non-overlapping planar orthogonal arrangement of n rectangular facilities within a given rectangular plan site so

as to minimize the distance based measure. Azadivar and Wang (2000) [29] defined that the facility layout problem as the determination of the relative locations for, and allocation of, the available space among a given number of facilities. Lee and Lee (2002) [30] had given the concept of arranging the facilities assuming unequal area of different sizes within a given total space. Shayan and Chittilappilly (2004) [31] reported the facility layout problem as an optimization problem that tries to make layouts more efficient by taking into account various interactions between facilities and material handling systems.

FACTORS WHICH AFFECTS THE PERFORMANCE OF ANY LAYOUT FOR ANY MANUFACTURING UNIT

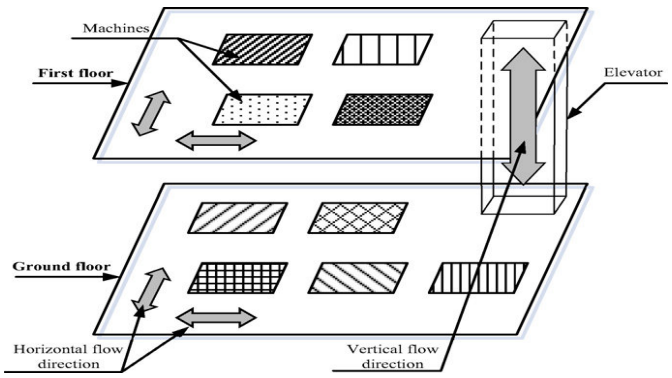
Depending on the product variety and their volume Four types of layout design are considered referred to in existing articles, namely 1) fixed product layout, 2) process layout,3) product layout and cellular layout (Dilworth,1996) [32].

Product layout or Line type layout: In this type the machines and auxiliary services in line according to the sequence of operations to be performed on the work. Process or functional layout: The primary requirement in process layout in flexibility, routing flexibility, volume flexibility. Fixed or static position layout: It is adopted when work piece is very big or too heavy to move from one position to the other and is consequently fixed in one place. In Cellular layout, machines are arranged into different cells, to process families of similar parts. As mentioned for example in (Proth, 1992, ch. 3) [33] and (Hamann & Vernadat, 1992) [34]. Here, one is concerned with finding the best arrangement of machines in each cell.

Material handling equipment such as conveyors (belt, roller, wheel), automated guided vehicles (AGV), robots, etc. (El-Baz, 2004) [35]. Tompkins et al. (1996) [36] had found that 20–50% of the manufacturing costs are due to the material handling parts and then a good arrangement of handling devices might to reduce them for 10–30%.Based on the type of material handling layout arrangement are classified as: single row layout, multi-rows layout, loop layout and open-field layout (Yang, Peters, & Tu, 2005) [37]. The problem occurs in case of when facilities have to be placed along a line (Djellab & Gourgand, 2001 [38]; Ficko, Brezocnick, & Balic, 2004 [39]; Kim, Kim, & Bobbie, 1996 [40]; Kumar, Hadjinicola, & Lin, 1995) [41]. Several shapes such as straight line, semicircular or U-shape may be considered (Hassan, 1994) [42]. In case of loop layout problem deals with the assignment of m facilities to candidate locations 1.., m, in a closed ring network, around which parts are transported in one direction (Chaieb, 2002 [43]; Cheng & Gen, 1998 [44]; Cheng, Gen, & Tosawa, 1996 [45]; Nearchou, 2006 [46]; Potts &Whitehead, 2001) [47].

Johnson (1982) [48] being as a first person among the first who has given the idea for multiple-floor layout problem. He had formulated with the problem of defining relative locations of facilities in a multiple-floor building. Further, more researchers focused to take consideration vertical movements of parts from sone floor to another (Bozer, Meller, & Erlebacher, 1994 [49]; Meller & Bozer, 1996, 1997) [50], [51]. The flow of a part, from one facility to another facility is called backtracking, preceding it in the sequence of facilities in the flow-line arrangement (Braglia, 1996 [52]; Kouvelis & Chiang, 1992 [53]; Zhou, 1998) [54]. The number of these movements has to be minimized. Zhou(1998) [54]. Dynamic layout

Problems takes consideration into valid changes in the material handling flow over multiple periods (Balakrishnan, Cheng,Conway, & Lau, 2003 [55]; Braglia, Zanoni, & Zavanella, 2003 [56]; Kouvelis, Kurawarwala, & Gutierrez, 1992 [57]; Meng, He ragu, & Zijm, 2004) [58].



Multi floor layout

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 (Kim & Kim, 1995 [59]; Leung, 1992 [60]; Proth, 1992 [33]) or neural network (Tsuchiya, Bharitkar, & Takefuji, 1996) [61]. 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 palnt as a discrete, the whole plant is divided into small rectangular area which is called as a facility (Fruggiero, Lambiase, & Negri, 2006) [62]. If facilities have unequal areas, they can occupy different blocks (Wang, Hu, & Ku, 2005) [63].

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) [64]:

$$\text{Minimum } T = \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} F_{ik} D_{jl} X_{ij} X_{kl}$$

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

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

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 (Das, 1993 [65]; Dunker et al., 2005 [66]; Meller et al., 1999) [67].

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 bottom-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) [68]:

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

The first mathematical model which is related to covering problems was developed by Toregas, Swain, ReVelle, and Bergman (1971) [69]. 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:

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

$$\sum_{j \in Ni}^{ST} Xj \geq 1 \quad i = 1\,2\,3 \ldots\ldots\ldots m$$

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

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:

$$\min = \sum_{j=1}^{n} C_j X_j$$

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

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

Classification of mathmatical model based on the problem of locating plants with material flow them

- Quadratic Assignment Model.
- Quadratic set covering Model.
- Linear Integer Programming model.
- Graph –Theoretic Approach.

INTELLIGENT TECHNIQUES FOR FACILITY LAYOUT PLANNING

Recently, in FLP expert techniques are used .An expert system in which the computer programme is used to imitate the decision making process of a human expert in a specific knowledge. Expert system using the major components user interface, Knowledge acquisition and engine interface. While using expert system techniques has given a revolutionary transition to knowledge processing.

FN 84 Fisher and Nof [70] had given, FADES which is a knowledge based approach for FLP.FADES is an ES designed for solving facility layout problems. **KKMM87** Kumara et al [71]. have modified a heuristic based ES.

INCORPORATION OF FUZZY LOGIC IN FLP, The type of fuzzy logic related to FLP are classified in the following way. **EWK87** Evans et al [72] have given a construction type fuzzy logic linguistic heuristic which is based on location of facility within a department. **RR93** Raoot and Rakshit [73] have a linguistic pattern for multiple FLP.

FUTURE SCOPE

In this article we have shown comprehensive study related to FLP. From above analysis we can conclude that articles which are related to different layout design continue to be published in main research journals and that facility layout remains an open research issue. Using of a third dimension when designing a plant is a recent consideration that definitively requires more research, example: selection and optimize resources which is related to the vertical transportation of parts between different floors. There is a need for research for designing the plant or workshop simultaneously instead of sequentially. Layout design problems also related with such as ports, markets airport etc. These are also the research area where modification can be done. As per different literature review, we consider two attributes for making future works directions:

- Covering problems on plane.
- Capacitate related facilities.
- Fuzzy parameters analysis.
- Multi-objective covering problems (many bi-objective Models are already have been covered) and considering non-cost objective functions.

Research can also be extended in dynamic covering allocation problems. Three future developments direction has been given by from Church and Murray (2009) [10] as follows:

– Backup coverage or multiple-coverage.

– For emergency facilities like fire stations and hospitals, service availability is applicable as an important Issue.

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