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A new model for dynamic multi floor facility layout problem

Abbas Afrazeh[1], Ali Keivani[2], Leila Najafabadi Farahani[1]

[1]Industrial Engineering Department, Amirkabir University of Technology, Tehran, Iran.

[2]Industrial Engineering Department, Mazandran University of Science & Technology

Abstract

The dynamic facility layout problem is the problem of assigning departments to the predetermined locations on the plant floor for multiple periods to minimize material handling and rearrangement costs. Nowadays, we encounters with shortage of lands to build factory, so we use of several floor. In this paper, we propose a mixed integer programming formulation for static and dynamic multi floor facility layout problem.

Keywords: Facility layout, Dynamic layout, Multi floor, Mixed integer programming.

1. Introduction

One of the oldest activities done by industrial engineers is facilities planning. The term facilities planning can be divided into two parts: facility location and facility layout (Tompkins et al., 2003). Determining the most efficient arrangement of physical departments within a facility is defined as a facility layout problem (FLP) (Garey and Johnson, 1973). Tompkins and White (1984) stated that 8% of the United States gross national product (GNP) has been spent on new facilities annually since 1955. Layout problems are known to be complex and are generally NP-Hard (Garey and Johnson, 1973).

There are several review research described facility layout problem carefully (see Loiola et al., 2007, Kulturel-Konak, 2007, Drira et al., 2007, Gu et al., 2007 and Liang and Chao, 2008). Loiola et al. 2007 was about facility layout as branch of quadratic assignment problem (QAP), Kulturel-Konak (2007) investigate facility layout problem under uncertain environment. Drira et al. (2007) proposed a structure to analyze layout problem, Gu et el. (2007) worked on warehouse layout, Liang and Chao (2008) express using tabu search (TS) algorithm in facility layout problem.

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In a basic layout design, each cell is represented by a rectilinear, but not necessarily convex polygon. The set of fully packed adjacent polygons is known as a block layout (Asef-Vaziri and Laporte, 2005). The two most general mechanisms in the literature for constructing such layouts are the flexible bay and the slicing tree (Arapoglu et al., 2001). A slicing structure can be represented by a binary tree whose leaves denote modules, and internal nodes specify horizontal or vertical cut lines (Wu et al., 2003). The bay-structured layout is a continuous layout representation allowing the departments to be located only in parallel bays with varying widths. The width of each bay depends on the total area of the departments in the bay (Konak et al., 2006).

One of common representation for facility layout is discrete representation. This representation is commonly used for dynamic layout problems. There are two approaches to designing robust and/or flexible facilities. The first approach, the dynamic facility layout problem (DFLP), considers several production periods, and facility layout arrangements are determined for each period by balancing material handling costs with the relayout costs involved in changing the layout between periods (Kulturel-Konak, 2006).

Recently, there are many researches in DFLP, Tavakoli-Moghadam et al. (2008) present an integer linear programming formulation for dynamic cell formation problem to minimize machine cost and inter-cell movement at the same time. Şahin and Türkbey (2008) developed a tabu-simulated annealing (TABUSA) for DFLP, Dong et al. (2009) consider adding or removing department in DFLP using simulated annealing (SA) algorithm, McKendall and Hakobyan (2010) developed TS algorithm to solve DFLP in large sized problem.

Nowadays, when it comes to construct a factory in urban area, land supply is generally insufficient and expensive. The limitation of available horizontal space creates a need to use a vertical dimension of the workshop. Then, it can be relevant to locate the facilities on several floor (Drira et al. 2007). Here, we state some work on multi floor facility layout problem. Meller and Bozer (1997) compared approaches of multi-floor facility layout. Lee et al (2005) used GA multi-floor layout which minimize total cost of materials transportation and adjacency requirement between departments while satisfied constraints of area and aspect ratios of departments. a five-segmented chromosome represented multi-floor facility layout. Many firms are likely to consider renovating or constructing multi-floor buildings, particularly in those cases where land is limited (Bozer et al 1994). Matsuzaki et al (1999) developed a heuristic for multi-floor facility layout with considering capacity of elevator. Patsiatzis et al (2002), presented a mixed integer linear formulation for multi-floor facility layout problem. This work was extended model of the single floor work of Papageorgiou and Rotstein (1998).

In this paper, we present a new exact model for both static and dynamic multi floor facility layout problem. At first, we propose mixed integer programming (MIP) formulation for static multi floor facility layout problem, and then we extend it to dynamic multi floor facility layout problem.

Remainder of paper is organized as follows: in section II, mathematical model is proposed, in section III, computational results are illustrated and in section IV, conclusions are discussed.

2. Mathematical model

Multi floor facility layout problem with equal area:

Assumptions:

All departments have a unit width and length.

Location of elevator is in the southern east corner of facility.

Sets and indices:

N: Set of departments $(|N| = n)$.

P: Set of locations $(|P| = p)$.

Variables:

$$X_{ip} = \begin{cases} 1, & \text{if department } i \text{ is located in location } p \\ 0, & \text{otherwise} \end{cases}$$

$$G_i = \begin{cases} 1, & \text{if department } i \text{ is located in second floor} \\ 0, & \text{otherwise} \end{cases}$$

C_{ij}: unit cost of material flow transportation between departments i and j in the same floor.

C_h: unit cost of material flow transportation between two floors.

Parameters:

f_{ij}: Material flow between departments i and j.

D_{pq}: distance between location p and q.

d_p: distance between location p and elevator.

H: distance between two floors.

Model:

$$Min \sum_{i\neq j}\sum_{j}\sum_{p}\sum_{q} C_{ij}G_iG_jf_{ij}X_{ip}X_{jq}D_{pq} + \sum_{i\neq j}\sum_{j}\sum_{p}\sum_{q}(1-G_i)G_jf_{ij}X_{ip}X_{jq}\left((d_p+d_q)C_{ij}+H.C_h\right)$$

$$\sum_{i} X_{ip} = 2 \qquad \forall p \qquad (1)$$

$$\sum_{p} X_{ip} = 1 \qquad \forall i \qquad (2)$$

Objective is to minimize material handling cost between two departments either in the same floor of in different floors. Constraint (1) states that each location can be filled by two departments; one department is first floor and the other in second floor. Constraint (2) states that each department can be filled only a location.

Dynamic Multi floor facility layout problem with equal area:

Assumptions:

All departments have a unit width and length.

Location of elevator is in the southern east corner of facility.

Sets and indices:

N: Set of departments $(|N| = n)$.

P: Set of locations $(|P| = p)$.

F: Finite horizon $(|F| = f)$

Variables:

$$X_{ipt} = \begin{cases} 1, & \text{if department } i \text{ is located in location } p \text{ in period } t \\ 0, & \text{otherwise} \end{cases}$$

$$G_{it} = \begin{cases} 1, & \text{if department } i \text{ is located in second floor in period } t \\ 0, & \text{otherwise} \end{cases}$$

C_{ij}: unit cost of material flow transportation between departments i and j in the same floor.

C_h: unit cost of material flow transportation between two floors.

F_l: unit cost of changing location a department in the same floor.

F_h: unit cost of changing location a department between two floors.

Parameters:

f_{ij}: Material flow between departments i and j.

D_{pq}: distance between location p and q.

d_p: distance between location p and elevator.

H: distance between two floors.

Model:

$$Min \sum_{i\neq j}\sum_{j}\sum_{p}\sum_{q}\sum_{t} C_{ij}G_{it}G_{jt}f_{ij}X_{ipt}X_{jqt}D_{pq}$$

$$+\sum_{i\neq j}\sum_{j}\sum_{p}\sum_{q}\sum_{t}(1-G_{it})G_{jt}f_{ij}X_{ipt}X_{jqt}\left((d_p+d_q)C_{ij}+H.C_h\right)$$

$$\sum_{i}\sum_{p}\sum_{q}\sum_{t>1}F_lG_{i(t-1)}G_{it}X_{ipt}X_{iqt}D_{pq}+\sum_{i}\sum_{p}\sum_{q}\sum_{t>1}\left(1-G_{i(t-1)}\right)G_{it}X_{ipt}X_{iqt}\left(HF_h+f_l\left(d_p+d_q\right)\right)$$

$$+\sum_{i}\sum_{p}\sum_{q}\sum_{t>1}G_{i(t-1)}(1-G_{it})X_{ipt}X_{iqt}\left(HF_h+f_l\left(d_p+d_q\right)\right)$$

$$\sum_{i} X_{ipt} = 2 \qquad \forall p,t \qquad (3)$$

$$\sum_{p} X_{ipt} = 1 \qquad \forall i, t \qquad (4)$$

Objective is to minimize material handling cost between two departments either in the same floor of in different floors addition to cost of changing location of department between two consequence periods. Constraint (3) states that each location can be filled by two departments in each period; one department is first floor and the other in second floor. Constraint (4) states that each department can be filled only a location in each period.

3. Computational results

We generate 5 test problems with 3, 5, 7, 10 and 15 departments. Input data include material flow matrix and parameters cost. For dynamic approach, we consider 4 periods. We solve model using CPLEX 10.1 in a PC with 1.00 GB RAM and 2.4 GHz CPU. Table 1 and Table 2 show solution for static and dynamic multi floor facility layout problem.

Table 1. Computational results for static multi floor layout

Size	Time (Sec)	Objective
3	10.0	145.6
5	50.0	256.3
7	298.6	563.2
10	745.3	765.3
15	1054.6	954.3

Table 2. Computational results for dynamic multi floor layout

Size	Time (Sec)	Objective
3	54.3	721.1
5	123.9	1038.0
7	543.2	2432.6
10	1936.4	2756.4
15	4598.3	4536.4

4.Conclusions

The dynamic facility layout problem is the problem of assigning departments to the predetermined locations on the plant floor for multiple periods to minimize material handling and rearrangement costs. Nowadays, we encounters with shortage of lands to build factory, so we use of several floor. In this paper, we proposed a mixed integer programming formulation for static and dynamic multi floor facility layout problem. For future research, it is proposed to consider input/output points location in designing facility layout problem.

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