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# An Extension of Block Layout Problem

M. Khosrojerdi, M. Bakhshayeshi Baygi, A. Molladavoudi, A. Hemmati, A. A. Jaafari

***Abstract*— In This paper, we extend a formulation for block layout problem. Objectives are to minimize departmental material handling cost and maximize closeness rating.**

***Index Terms* — Facility layout, Block layout, Mixed integer programming, Multi-objective.**

## I. 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. The latter is one of the foremost problems of modern manufacturing systems and has three sections: layout design, material handling system design and facility system design (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 Jhonson 1979). Layout problems are known to be complex and are generally NP-Hard (Garey and Jhonson 1979). For more detailed studying in facility layout problem, readers are referred to these references: (Dira et al. 2007), (Loiola et al. 2007) and (Singh and Sharma 2006).

In a typical layout design, each cell is represented by a rectilinear, but not necessarily a convex polygon. The set of the fully packed adjacent polygons is known as a block layout (Farahani et al. 2007). The two most general mechanisms in the literature for constructing such layouts are the flexible bay and the slicing tree (Arapoglu et al. 2001).

(Lee et al. 2008) propose a mixed integer programming (MIP) formulation and develop two heuristic based on MIP model for designing network flow in a block layout. (Kelachankuttu et al. 2007) consider contour line in rectangular-department facility to place the new facility in the best way.

Classical approach to facility layout is to minimize material handling cost. However, in real world cases, the designer interfaces with many multiple conflicting objectives to facility design. There are some works in literature which deal with multi-objective facility layout problems that are described here.

In this paper, we extend a mixed integer programming formulation for facility layout problem that was presented by Montruiel et al. They consider single objective, minimizing departmental material handling cost. According to literature, there is no formulation for multi-objective facility layout problem. Our formulation involves both minimizing departmental material handling cost and maximizing closeness rating.

M. Khosrojerdi, M. Bakhshayeshi Baygi, A. Molladavoudi, A. Hemmati, A. A. Jaafari are with the Department of Industrial Engineering, Amirkabir University, Tehran, Iran (e-mail: ardestani.amir@aut.ac.ir)

## II. Mathematical Formulation

### A. Parameter

$N$ Number of departments,
$W$ Width of the facility along the x-axis,
$H$ Length of the facility along the y-axis,
$a_i$ Area requirement of department i,
$\alpha_i$ Aspect ratio of department i,
$l_i^{max}$ Maximum permissible side length of department i
$l_i^{min}$ Minimum permissible side length of department i

### B. Variables

$N$ Number of departments,
$W$ Width of the facility along the x-axis,
$H$ Length of the facility along the y-axis,
$a_i$ Area requirement of department i,
$\alpha_i$ Aspect ratio of department i,
$l_i^{max}$ Maximum permissible side length of department i
$l_i^{min}$ Minimum permissible side length of department i

$$z_{ij}^x = \begin{cases} 1, & \text{If department } i \text{ is front of department } j \text{ in x-axis without any common boundary} \\ 0, & \text{Otherwise} \end{cases}$$

$$z_{ij}^y = \begin{cases} 1, & \text{If department } i \text{ is above department } j \text{ in y-axis without any common boundary} \\ 0, & \text{Otherwise} \end{cases}$$

### C. Formulation

$$d_{ij}^x \geq |o_i^x - o_j^x| \qquad \forall i < j \qquad (1)$$
$$d_{ij}^y \geq |o_i^y - o_j^y| \qquad \forall i < j \qquad (2)$$
$$l_i^{min} \leq o_i'^x - o_i''^x \leq l_i^{max} \qquad \forall i \qquad (3)$$
$$l_i^{min} \leq o_i'^y - o_i''^y \leq l_i^{max} \qquad \forall i \qquad (4)$$
$$(o_i'^x - o_i''^x)(o_i'^y - o_i''^y) = a_i \qquad \forall i \qquad (5)$$
$$0 \leq o_i'^x \leq o_i''^x \leq W \qquad \forall i \qquad (6)$$
$$0 \leq o_i'^y \leq o_i''^y \leq H \qquad \forall i \qquad (7)$$
$$o_i^x = o_i'^x + o_i''^x \qquad \forall i \qquad (8)$$

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$o_i^y = o_i'^y + o_i''^y \quad \forall i \quad (9)$

$o_i''^x \leq o_i'^x + W\left(1 - z_{ij}^x\right) \quad \forall i,j \quad (10)$

$o_i''^y \leq o_i'^y + W\left(1 - z_{ij}^y\right) \quad \forall i,j \quad (11)$

$z_{ij}^x + z_{ji}^x \leq 1 \quad \forall i,j \quad (12)$

$z_{ij}^y + z_{ji}^y \leq 1 \quad \forall i,j \quad (13)$

$z_{ij}^x + z_{ji}^x + z_{ij}^y + z_{ji}^y \geq 1 \quad \forall i,j \quad (14)$

$$Co_{ij} = \begin{pmatrix} min\left(o_i^y + 0.5l_i^y, o_j^y + 0.5l_j^y\right) \\ -max\left(o_i^y - 0.5l_i^y, o_j^y - 0.5l_j^y\right) \end{pmatrix} + \begin{pmatrix} min\left(o_i^x - 0.5\sum_k w'_{ik}, o_j^x - 0.5\sum_k w'_{jk}\right) \\ -max\left(o_i^x + 0.5\sum_k w'_{ik}, o_j^x + 0.5\sum_k w'_{jk}\right) \end{pmatrix}$$

Constraint (4) is linearized as follow:

$Up_i^y = o_i^y + 0.5l_i^y \quad \forall i \quad (15)$

$Up_i^x = o_i^x + \sum_k w'_{ik} \quad \forall i \quad (16)$

$Low_i^y = o_i^y - 0.5l_i^y \quad \forall i \quad (17)$

$Low_i^x = o_i^x - 0.5\sum_k w'_{ik} \quad \forall i \quad (18)$

$E_{ij}^x \leq Up_i^x \quad \forall i < j \quad (19)$

$E_{ij}^x \leq Up_j^x \quad \forall i < j \quad (20)$

$E_{ij}^y \leq Up_i^y \quad \forall i < j \quad (21)$

$E_{ij}^y \leq Up_j^y \quad \forall i < j \quad (22)$

$F_{ij}^x \leq low_i^x \quad \forall i < j \quad (23)$

$F_{ij}^x \leq low_j^x \quad \forall i < j \quad (24)$

$F_{ij}^y \leq low_i^y \quad \forall i < j \quad (25)$

$F_{ij}^y \leq low_j^y \quad \forall i < j \quad (26)$

$Co_{ij} = \left(E_{ij}^x - F_{ij}^x\right) + \left(E_{ij}^y - F_{ij}^y\right) \quad \forall i < j \quad (27)$

$$\text{Min } p\sum_i\sum_{i<j} f_{ij}\left(d_{ij}^x + d_{ij}^y\right) - (1-p)\sum_i\sum_{i<j} Co_{ij}y_{ij} \quad 0 \leq p \leq 1 \quad (28)$$

Objective is linearized as follows:

$Co'_{ij} \leq (W + H)y_{ij} \quad \forall i < j \quad (29)$

$Co'_{ij} \leq Co_{ij} + (W + H)y_{ij} \quad \forall i < j \quad (30)$

$Co'_{ij} \geq Co_{ij} - (W + H)y_{ij} \quad \forall i < j \quad (31)$

$$\text{Min } z_1 = p\sum_i\sum_{i<j} f_{ij}\left(d_{ij}^x + d_{ij}^y\right) \quad 0 \leq p \leq 1 \quad (32)$$

$$z_2 = -(1-p)\sum_i\sum_{i<j} Co'_{ij}$$

## VI. COMPUTATIONAL RESULTS

We run a set of tests problem sizing range between 3 to 5 for $p = 0.1, 0.3, 0.5, 0.7, 0.7$. Table 1. Shows the computational results as follows.

Table 1. Computational Results

| p | | 3 | 4 | 5 |
|---|---|---|---|---|
| 0.1 | Z1 | 13.2 | 13.52 | 9.6 |
| | Z2 | 54.3 | 57.73 | 20.4 |
| 0.3 | Z1 | 16.8 | 16.48 | 11.3 |
| | Z2 | 37.6 | 39.36 | 19.6 |
| 0.5 | Z1 | 19.4 | 22.34 | 13.1 |
| | Z2 | 31.3 | 32.43 | 17.6 |
| 0.7 | Z1 | 21.4 | 24.54 | 15.1 |
| | Z2 | 24.3 | 26.73 | 15.1 |
| 0.9 | Z1 | 29.6 | 35.56 | 18.1 |
| | Z2 | 20.4 | 22.44 | 10.4 |

## VI. CONCLUSIONS

In this paper, we extended a mixed integer programming formulation for block layout problem that was presented by Montruile et al. [8]. According to literature, there is no formulation for multi-objective facility layout problem. Our formulation involved both minimizing departmental material handling cost and maximizing closeness rating

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