The Continuous Facility Layout Problem with Determination of Entrance and Exit Location

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Abstract

The continuous facility layout problem with determination of entrance and exit location is addressed in this study. This study extends the basic continuous facility layout model by considering entrance and exit location which are location of material in flow and out flow of each facility. This extension is described as mathematical constraints and be added into the basic continuous facility layout model. The problem is formulated as Mixed Integer Programming and then solve by CPLEX Solver. Moreover for the problems with medium size a Partitioning heuristic is developed to solve the problem within this size. The computational result shows that heuristic can solve problems up to 50 departments within two hours. Moreover the heuristic shows better solution 50.44% within limited time.

Keywords*: Continuous facility layout problem, entrance and exit location, Heuristic, Optimization*

1 Introduction

The factory layout decision is one of the main decisions in facility management for both service and manufacturing shop floor management. The main objective of the problem is to determine good locations for a given set of departments on some workshop floor. This kind of problem usually called facility layout problem (FLP). The main indictor of the good layout is the flow cost between departments which evaluate by the distance and material flow among them. Moreover, other criteria such as workforce requirements, work-in-process inventory, may be considered as alternative objective or as side constraints. Whatever the objective are, the good solution frequently to be certain departments need to be physically close to each other. Unfortunately sometime decision maker cannot satisfy all the needs that each department must be placed next to each other. One has to determine for each department which department it should be placed next to. In order to find the location of each department many researcher put effort to obtain the good solution which can read further in the work of Balakrishnan and Cheng [1] and Singh and Sharma [2], for a survey of different methods. Balakrishnan et al. [3] studied the problem which considered limited budget of rearrangement costs and use a constrained shortest path algorithm which proposed by Mote et al. [4].

Kochhar and Heragu [5] proposed the algorithm which reduces the problem to a problem with a fixed initial layout and improvement it. The case of the fixed rearrangement cost problem is studied by Urban [6] and Balakrishnan et al. [7]. Yang and Peters [8] propose a specific method for the problem and use improvement methods.

The increasing complexity of the problem leads to heuristic methods, so many authors propose heuristic algorithm to obtain ‘‘good’’ solutions, see e.g., Kaku and Mazzola [9], Baykasoglu and Gindy [10], or Ramana et al. [11].

This paper researcher proposes a genetic algorithm for the problem. For finding a sequence of layouts that obtains a good solution. The remainder of this paper is organized as follows. In Section 2 we introduce a mathematical model for the problem. Section 3 presents solution method. Section 4 contains experimental design. The result is shown in section 5. Finally, the discussion on numerical experiments and comparison is presented in Section 6.

2 Problem description

This paper considers a continuous facility layout problem which comprises of a set of departments indexed $i \in N = \{1,2,...,n\}$ with given width and length for each department. These departments must be considered to locate within an unlimited area of a shop floor. The coordinate in x-axis and y-axis of each department are investigated for its location in available are. Moreover the entrance and exit of each department must be determined as the point that the material in the shop floor can flow in and out thru these points. The objective of the decision is to minimize the total flow distance between departments. The model formulation of the considered facility layout problem is shown as follow:

Decision Variables

x_i	Coordination of the left-bottom corner of department *i* in x-axis.
y_i	Coordination of the left-bottom corner of department *i* in y-axis.
o_i	1 If orientation of department *i* is portrait, 0 otherwise.
l_{ij}	1 If department i locates on the left side of department j, 0 otherwise.
r_{ij}	1 If department *i* locates on the right side of department *j*, 0 otherwise.
t_{ij}	1 If department *i* locates on the top side of department *j*, 0 otherwise.
b_{ij}	1 If department *i* locates on the bottom side of department *j*, 0 otherwise.
x_i^{ent}	Coordination of the entrance of department *i* in x-axis.
y_i^{ent}	Coordination of the entrance of department *i* in y-axis.
x_i^{ext}	Coordination of the exit of department *i* in x-axis.
y_i^{ext}	Coordination of the exit of department *i* in y-axis.
r_i^{ent}	1 If entrance point of department *i* locates at Right edge of the department area, 0 otherwise.
l_i^{ent}	1 If entrance point of department *i* locates at Left edge of the department area, 0 otherwise.
t_i^{ent}	1 If entrance point of department *i* locates at Top edge of the department area, 0 otherwise.
b_i^{ent}	1 If entrance point of department *i* locates at Bottom edge of the department area, 0 otherwise.
r_i^{ext}	1 If exit point of department *i* locates at Right edge of the department area, 0 otherwise.
l_i^{ext}	1 If exit point of department *i* locates at Left edge of the department area, 0 otherwise.
t_i^{ext}	1 If exit point of department *i* locates at Top edge of the department area, 0 otherwise.
b_i^{ext}	1 If exit point of department *i* locates at Bottom edge of the department area, 0 otherwise.

Set

$N = \{1..n\}$ Department Set.

Parameters

w_i	Width of the department *i*.
l_i	Length of the department *i*.
f_{ij}	Flow amount from department *i* to *j*.
M	Very large Value

Mathematical Model

$$\text{Minimize } f_{ij}(\left|x_i^{ext} - x_i^{ent}\right| + \left|y_i^{ext} - y_i^{ent}\right|) \tag{0}$$

S.T.

$$x_i + w_i o_i + l_i(1-o_i) \le x_j + M(1-l_{ij}) \qquad \forall i, j \in N; i \ne j \tag{1}$$

$$x_j + w_j o_j + l_j(1-o_j) \le x_i + M(1-r_{ij}) \qquad \forall i,j \in N; i \ne j \qquad (2)$$

$$y_i + w_i(1-o_i) + l_i o_i \le y_j + M(1-b_{ij}) \qquad \forall i,j \in N; i \ne j \qquad (3)$$

$$y_j + w_j(1-o_j) + l_j o_j \le y_i + M(1-t_{ij}) \qquad \forall i,j \in N; i \ne j \qquad (4)$$

$$l_{ij} + r_{ij} + t_{ij} + b_{ij} = 1 \qquad \forall i,j \in N; i \ne j \qquad (5)$$

$$x_i^{ent} \le x_i + w_i o_i + l_i(1-o_i) + M(1-r_i^{ent}) \qquad \forall i \in N \qquad (6)$$

$$x_i^{ent} \ge x_i + w_i o_i + l_i(1-o_i) - M(1-r_i^{ent}) \qquad \forall i \in N \qquad (7)$$

$$x_i^{ent} \le x_i + M(1-l_i^{ent}) \qquad \forall i \in N \qquad (8)$$

$$x_i^{ent} \ge x_i - M(1-l_i^{ent}) \qquad \forall i \in N \qquad (9)$$

$$y_i^{ent} \le y_i + w_i(1-o_i) + l_i o_i + M(1-t_i^{ent}) \qquad \forall i \in N \qquad (10)$$

$$y_i^{ent} \ge y_i + w_i(1-o_i) + l_i o_i - M(1-t_i^{ent}) \qquad \forall i \in N \qquad (11)$$

$$y_i^{ent} \le y_i + M(1-b_i^{ent}) \qquad \forall i \in N \qquad (12)$$

$$y_i^{ent} \ge y_i - M(1-b_i^{ent}) \qquad \forall i \in N \qquad (13)$$

$$r_i^{ent} + l_i^{ent} + t_i^{ent} + b_i^{ent} = 1 \qquad \forall i \in N \qquad (14)$$

$$x_i^{ext} \le x_i + w_i o_i + l_i(1-o_i) + M(1-r_i^{ext}) \qquad \forall i \in N \qquad (15)$$

$$x_i^{ext} \ge x_i + w_i o_i + l_i(1-o_i) - M(1-r_i^{ext}) \qquad \forall i \in N \qquad (16)$$

$$x_i^{ext} \le x_i + M(1-l_i^{ext}) \qquad \forall i \in N \qquad (17)$$

$$x_i^{ext} \ge x_i - M(1-l_i^{ext}) \qquad \forall i \in N \qquad (18)$$

$$y_i^{ext} \le y_i + w_i(1-o_i) + l_i o_i + M(1-t_i^{ext}) \qquad \forall i \in N \qquad (19)$$

$$y_i^{ext} \ge y_i + w_i(1-o_i) + l_i o_i - M(1-t_i^{ext}) \qquad \forall i \in N \qquad (20)$$

$$y_i^{ext} \le y_i + M(1-b_i^{ext}) \qquad \forall i \in N \qquad (21)$$

$$y_i^{ext} \ge y_i - M(1-b_i^{ext}) \qquad \forall i \in N \qquad (22)$$

$$r_i^{ext} + l_i^{ext} + t_i^{ext} + b_i^{ext} = 1 \qquad \forall i \in N \qquad (23)$$

$$x_i^{ent} \ge x_i \qquad \forall i \in N \qquad (24)$$

$$x_i^{ent} \le x_i + w_i o_i + l_i(1-o_i) \qquad \forall i \in N \qquad (25)$$

$$y_i^{ent} \geq y_i \qquad \forall i \in N \qquad (26)$$

$$y_i^{ent} \leq y_i + w_i(1-o_i) + l_i o_i \qquad \forall i \in N \qquad (27)$$

$$x_i^{ext} \geq x_i \qquad \forall i \in N \qquad (28)$$

$$x_i^{ext} \leq x_i + w_i o_i + l_i(1-o_i) \qquad \forall i \in N \qquad (29)$$

$$y_i^{ext} \geq y_i \qquad \forall i \in N \qquad (30)$$

$$y_i^{ext} \leq y_i + w_i(1-o_i) + l_i o_i \qquad \forall i \in N \qquad (31)$$

Description of Constraints
(0) Objective Function.
(1)-(4) Overlapping of departments is prohibited.
(5) There must be only one relationship type between department *i* and *j*.
(6)-(13) Relationship between coordination of the entrance of department and entrance point decision.
(14) There must be only one relationship type between coordination of the entrance of department and entrance point decision.
(15)-(22) Relationship between coordination of the exit of department and exit point decision.
(23) There must be only one relationship type between coordination of the exit of department and exit point decision.
(24)-(31) Boundary of entrance and exit coordination.

3 Solution Method

The problem considered in this paper can easily be noticed its complexity as NP-Hard problem. These kinds of problem usually be solved by heuristic algorithms. In this paper a Partitioning algorithm embedded with Mixed Integer Program are proposed to solve this complex problem.

Initial Solution

The Model presented in Section 2 is solved with limit time of 5 minutes to obtain an initial solution for the remaining algorithm. The reason using 5 minutes is from the prelim experiment that the objective value is converted into some value after 5 minutes.

Set Group of Fixed Location Departments

After obtain an initial solution we try to partition the departments into groups. Firstly the centre point of the layout is calculated by the following equation (10) and (11).

$$x_{center} = \frac{\sum_i x_i \sum_j f_{ij}}{\sum_i \sum_j f_{ij}} \qquad (10)$$

$$y_{center} = \frac{\sum_i y_i \sum_j f_{ij}}{\sum_i \sum_j f_{ij}} \qquad (11)$$

The departments are partitioned into 4 groups which determined by the relative location of each department. The first group contains with all departments that the left-bottom coordination lays within the left-top zone relative to the center point. The second group contains with all departments that the coordination lays within the right-top zone relative to the center point. The third and the last group contains with all departments that the coordination lays within the right-bottom and left-bottom zone relative to the center point respectively. An illustration of four zones is shown in figure 1.

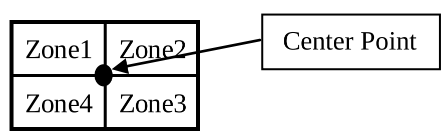

Figure 1: Four zones of departments.

Iteratively Solved by MIP Solver

For each group which partitioned, the location of them is determined by the MIP Solver by fixed location of other groups with limit time of 120 seconds. If the improvement of objective value found in any group the solution of solving that group location is selected to be the initial solution for the next iteration.

Terminating Condition

If all partitioned group is solved by MIP solver and found no improvement on objective value the algorithm is terminated.

4 Experimental Design

The various problems range from 10 to 50 departments are generated by random the flow between department with uniform distribution Uniform [1,100]. The width and length of department also are randomly generate by uniform distribution Uniform [10,100]. The solutions from heuristic are compared by solutions from CPLEX 12.2 MIP solver with limit computation time at two hours. Each size of problem is tested by three instances for performance comparison. The DUO CORE 1.8 GHz Personal Computer is used for computing the algorithm.

5 Computational Result

The result shown in Table1 indicates that the proposed method can solve the problem more efficient than exact algorithm within two hours which is reasonable time. The computational time of exact algorithm shows that hardness of solving this kind of problem. The proposed algorithm can performs up to 50.44% better result than solution from standard MIP solver solution with limit time.

Table 1: Computation Result

Test ID	Problem Size	Cost			Time (sec)		
		Exact Method	Heuristic	Compare(%)	Exact Method	Heuristic	Compare(%)
1	10	94,927.00	90,074.00	5.11%	7200	385.02	94.65%
2	10	111,804.00	111,804.00	0.00%	7200	332.08	95.39%
3	10	80,556.00	79,517.00	1.29%	7200	364.19	94.94%
4	20	1,405,532.00	973,140.00	30.76%	7200	1841.40	74.43%
5	20	1,240,668.00	954,835.00	23.04%	7200	1860.00	74.17%
6	20	1,050,978.00	875,382.00	16.71%	7200	1875.20	73.96%
7	30	4,108,844.00	2,512,645.00	38.85%	7200	2436.75	66.16%
8	30	3,807,419.00	2,563,210.00	32.68%	7200	2512.50	65.10%
9	30	4,178,612.00	3,241,053.00	22.44%	7200	2411.20	66.51%
10	40	9,660,380.00	6,512,030.00	32.59%	7200	2851.30	60.40%
11	40	11,784,807.00	6,951,203.00	41.02%	7200	3210.50	55.41%
12	40	11,156,779.00	8,451,203.00	24.25%	7200	3052.50	57.60%
13	50	20,720,581.00	13,521,510.00	34.74%	7200	3612.50	49.83%
14	50	22,299,909.00	11,051,230.00	50.44%	7200	3421.25	52.48%
15	50	22,356,436.00	12,054,866.00	46.08%	7200	3600.00	50.00%

6 Conclusions

This paper proposed a heuristic algorithm with MIP-Based for solving continual facility layout problem with determination of exit and exit. The result showed that the heuristic can efficiently solved the problem within reasonable time compared to the exact method with CPLEX Solver.

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