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Multi Objective Simulated Annealing Approach for Facility Layout Design

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Abstract
Facility layout design problem considers the departments' physcial layout design with area requirements in some restrictions such as material handling costs, remoteness and distance requests. Briefly, facility layout problem related to optimization of the layout costs and working conditions. This paper proposes a new multi objective simulated annealing algorithm for solving of the unequal area in layout design. Using of the different objective weights are generated with entropy approach and used in the alternative layout design. Multi objective function takes into the objective function and constraints. The suggested heuristic algorithm used the multi-objective parameters for initialization. Then prefered the entropy approach determines the weight of the objective functions. After the suggested improved simulated annealing approach applied to whole developed model. A multi-objective simulated annealing algorithm is implemented to increase the diversity and reduce the chance of getting layout conditions in local optima.

Keywords- Heuristics, Manufacturing, Multi objective simulated annealing algorithm, Unequal-area facilities, Entropy, Manufacturing facility layout design.

1. Introduction

Facility layout design problem is designing the layout of departments with some restrictions which are material handling costs, remoteness and distance requests. The multi objective Facility Layout Problem (FLP) close to optimization of the layout costs and the location of facilities (e.g., machines, departments) in a plant.

FLP is related to the location of facilities (machines, departments, etc.) and it is able to affect the system performance. Facility layout is associated to allocation of the activities to space such that a set of criteria (for example, area requirements) met of the some objectives are optimized. Suggested heuristic algorithm uses the entropy approach for determine the each objective function weight value. The main aim is minimize the materail handling cost and time with using efficient space in layout design. When the problem size increases, computational time and technique is getting hard for this reason FLPs are complex and NP-hard. Drira et al. offered a comprehensive FLP review, covering a wide spectrum of concepts ranging from its definitions, manufacturing systems, facility shapes, etc. to solution approaches, constraints, objectives, etc.

Heuristic methods are grouped into two groups the procedural and algorithmic themselves. The procedural approach such as the systematic layout planning realizes the facility layout design in three stages the analysis, search, and selection (Yang and Kuo, 2003). Also, the algorithmic approaches are divided in two classes, i.e., the constructed and improved the simulated annealing algorithm. The constructed algorithmic approaches as ALDEP (Seehof and Evans, 1967) and COROLAP (Lee and Moore, 1967) and the improved algorithmic approaches as CRAFT

(Armour and Buffa, 1963) and COFAD (Tompkins and Reed, 1976) are samples of these methods. Note that these methods have some limitations.

Many authors have used the metaheuristics approaches to obtain the near-optimal designs with simulated annealing approach to solve FLP (Al-Araidah et al., 2006; Khilwani et al., 2008; Singh and Singh, 2010; Chwif et al., 1998; McKendall et al., 2006; Ariafar and Ismail, 2009). Singh and Sharma (2008) and Şahin and Türkbey (2009) studied the simulated annealing approaches for the design of the facility layout design problems.

The proposed algorithm used the heuristic approach with initial solutions which are randomly generated and improved to yield the final suboptimal solution. This algorithm consists of three stages: the initial solution is constructed in the first stage, then the second stage used the entropped the weight values and the output of the second stage is improved in the third stage. The third stage of the algorithm is itself comprised of three different types of algorithms. These constituent algorithms are similar in that they both support unequal-area facilities, and their difference lies in the fact that one can accept any facility shape whereas the other only accepts rectangular facilities. Algorithms presented here are suitable for hierarchical layouts; therefore, it is recommended that space for facilities, operators and other requirements form workstations, workstations form departments and departments form the whole factory.

The remainder of paper structured as follows. In Section 2, multi objective facility layout problems reviewed. In Section 3, multi objective facility layout problem's mathematical model designed and recognized. The suggested multi objective simulated annealing algorithm represented in Section 4, the structural characteristics of the problem and the formulation approaches applied in Section 5. Finally, Section 6 provides conclusions and some research directions to be investigated in future research work.

2. Literature Review

FLP is so important for industrial engineers for this reason it applied in the wide area in real life and it is well designed and researched problem in academics. FLP is characterized as the problem of locating facilities in a limited area such that associated layout costs are minimized. Layout costs arise from various sources including material handling cost and time, and slack area. FLP aims to reduce material handling costs, work in process, lead times, utilize existing space more effectively and efficiently. In the beginning, the facilities are designed in several types of manufacturing systems then adopted the different areas such as construction sites, manufacturing industry and service industries and service sectors like supermarket, hospital. The problem of designing a physical layout of plant departments' main objective is minimizing the total material handling and layout costs which are time and slack area. Drira et al. 2007 reviewed the facility layout problems. Shayan and Chittilappilly (2004) defined 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 while designing layouts. Taghavi and Murat (2011) suggested the perturbation algorithm and sequencial location analysis insted of the integrated facility layout design and flow assignment problem with nonlinear mixed integer model. Saraswat et al. (2015) used the flow-distance parameters in framework for multi-objective design and Defresh and Hodiya (2017) suggested mathematical model for improving of the materail handling efficiency. Ahmadi et al. (2017) realized the literature survey for facility layout design problems.

Allahyari and Azab (2015) suggested the unequal area based bi-level facility layout problem mathematical model and heuritstic algorithm. Rossin classified the complexity measures of the facility layout problems. As defined in the literature, the objective of the layout design problem is the minimization of the material handling cost within a facility taking into consideration the following two sets of constraints: (a) departmental and floor area requirements and (b) departmental locational restrictions. Constraints set (a) ensures departments are located within the given perimeters of the plant, while constraints set (b) prevents departments from overlapping (Castillo and Sim, 2004; Chiang and Kouvelis, 1996; Heragu and Kusiak, 1991; Meller and Gau, 1996). Jankovits et al. (2011) developed mathematical model and the convex optimization framework for unequal-areas facility layout problem. Defersha and Hodiya (2017) modeled the integrated distributed layout design.

Several solution methods for FLP are developed in the literature; these can be categorized as follows: (1) exact optimization approaches, (2) heuristics, and (3) metaheuristics. The authors find the taxonomy provided by Drira et al. (2007) to be quite comprehensive; few issues are noted, though. Firstly, the authors in their figure one summarizing their classification are mistakenly labeling the first category as "Manufacturing System".

The proposed algorithm of this paper is classified as a heuristic improvement algorithm since initial solutions are randomly generated and improved to yield the final suboptimal solution. This algorithm consists of two stages: the initial solution is constructed in the first stage and the output of the first stage is improved in the second stage. The second stage of the algorithm is itself comprised of two different types of algorithms. These constituent algorithms are similar in that they both support unequal-area facilities, and their difference lies in the fact that one can accept any facility shape whereas the other only accepts rectangular facilities. Algorithms presented here are suitable for hierarchical layouts; therefore, it is recommended that space for facilities, operators and other requirements form workstations, workstations form departments and departments form the whole factory. These algorithms are tested for various runs of the algorithm with different parameter settings to acquire their running time in each case. A user interface is designed to monitor performance of the algorithm via dynamic modification of parameters while algorithms are running which is called FLCD (Facility Layout Collision Detection).

Singh and Singh (2010) suggested the Multi-Objective Facility Layout Problem (MOFLP) model which generates a different layout by varying objectives weights and they demonstrated the objective weights important role in the layout design of MOFLP. In practice, it is selected randomly by the layout designer based on his/her past experience that restricts the layout designing process completely designer dependent and thus the layout varies from designer to designer. This study suggested the entreopy approach for the objective weights.

A comprehensive mathematical model for pure continuous detailed MOFLP is presented. The developed model can be used in manufacturing systems, where different carriers with different capacities are used to transport parts among facilities/department.

3. Facility Layout Design

FLP is an important problem which is defined as the problem of locating facilities in a limited area and resources. These are NP-complete that means the amount of computation increases exponentially with problem size. In this study, unequal-area constraints are considered in the multi-facility layout design mathematical model that is applied on the suggested improved simulated annealing approach. Layout costs arise from various sources including material handling, time, and slack area. The multi-objective facility layout design steps are given below. In this section the multi-facility layout desig in model functions reviewed which based on the objective functions, constraints and decision variables.

A multi-objective facility layout design steps:

STEP 1: Data collection.
STEP 2: Determine of the space requirements of the current plan and required plan.
STEP 3: Consider the relationship diagram and space relationship diagram.
STEP 4: Modeling of the objective function.
STEP 5: Determine and modeling of the constraints.
STEP 6: Analysis of the flow analysis-quantitative analysis and space availability.
STEP 7: Analysis of the objective function with constraints using of the simulated annealing approach.
STEP 8: Determine of the optimum facility layout plan.

The model also considers the capacity changes along time, as well as changes in the transportation costs between facilities. This multi-objective model is designed considering the total material handling costs, the reconfiguration costs, the remoteness function with adjacaceny of the departments (due to the importance of locating high affinity departments at the same facility), and a new objective designated as unsuitability. The unsuitability between departments and locations has a special importance for layout reconfigurations, since it somehow measures the adequacy of the features of each location to the requirements of each department.

3. Mathematical Model

In this section, multi objectives facility layout functions are presented in mathematical model. Contraints express to the system restrictions with considering of the resources. After the optimization process system considers the satisfaction degree, efficieny and maksimum profit. This study considers the unequal size.

The facility layout problem considered the arranging of n unequal-area facilities in sizes $w_i \times l_i$, where w_i and l_i are the given width and the length of each facility, respectively, $i=1,\ldots,n$, within a given total space which can be bounded to the length or width of site area in a way to minimize the total material handling cost, reconfiguration cost, remoteness function, using of the area, unsuitability between departments (Eq. 1). The material handling cost between facility i and j is given by $c_{ij}f_{ij}d_{ij}$ where c_{ij} is the cost of one unit of flow between i and j, f_{ij} is the amount of flow between i and j, and d_{ij} is the distance between i and j.

The MFLP allocates departments at different facilities, taking into consideration transportation costs and operational constraints between facilities.

The problem is formulated under the following assumptions:

(i) Facilities are unequal size.
(ii) Facilities must be located within a given area.
(iii) Facilities must not overlap with each other.
(iv) The demand is known.

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The following practical considerations were taken into account when formulating the developed model; these were ignored by Heragu and Kusiak (1991).

Indices

Z	objective function value for Multi Objective Facility Layout Design
p	number of objectives
F	number of facilities
N	number of characteristics to evaluate the *suitability* between departments and locations
n	the number of departments in the layout, the area

Parameters

x_{ij}	the 0,1 varaible for locating departments *i* and location *j*
f_{ij}	work flow from facility *i* to facility *k*
c_{ij}	the unit cost (the cost to move one unit load one distance)
d_{ij}	distance from location *j* to location *l*
l_{ij}	the contact premier length between departments *i* and *j*
r_{ij}	the remoteness rating
Cr	total reconfiguration cost
L_{ij}	length of the two dimensional rectangle
W_{ij}	width of the two dimensional rectangle
cr_i	cost of shifting department *i*
α	objective weight for the materail handling cost
β	objective weight for the remoteness function
θ	objective weight for using of the area
δ	objective weight for reconfiguration cost

Decision Variables

$x_{i(f,l)t}$	1,	if department *i* is placed at position *l*, in facility *f*, in period *t*;
	0,	otherwise.
D_j		Demand quantity for material *j*;
U_{joi}	1,	if operation o of material *j* can be done by facility *i*;
	0,	otherwise.

The objective function is:

$$\text{Min } Z=f(x) = \alpha \textstyle\sum_{\mathrm{i}} \sum_{\mathrm{j}} (f_{ij} c_{ij}) \mathrm{x}_{ij} d_{ij} + \beta \sum_{\mathrm{i}} \sum_{\mathrm{j}} (r_{ij} l_{ij}) \mathrm{x}_{ij} + \theta \tag{1}$$

(i) Material Handling Cost

The first objective function is material handling cost which is applied to unequal area in FLP.

$$\alpha \textstyle\sum_{\mathrm{i}} \sum_{\mathrm{j}} (f_{ij} c_{ij}) \mathrm{x}_{ij} d_{ij} \tag{2}$$

(ii) Remoteness Function

Minimization of the remoteness function uses the r_{ij} remoteness rating variable and l_{ij}.

$$\beta \textstyle\sum_{\mathrm{i}} \sum_{\mathrm{j}} (r_{ij} l_{ij}) \mathrm{x}_{ij} \tag{3}$$

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(iii) Using of the Area
This function evaluates the departments located in the facility properly.

$$\theta \sum_i \sum_j \left(\frac{\min\{L_{ij}, W_{ij}\}}{\max\{L_{ij}, W_{ij}\}}\right) x_{ij} \quad (4)$$

(iv) Reconfiguration Cost
The model considers the total costs of reconfiguring a layout with below equation.

$$\delta \sum_i \sum_j (Cr_{ij} x_{ij}) \quad (5)$$

Model constraints are:

$$\alpha + \beta + \theta + \delta + \varphi = 1 \quad (6)$$

(v) Budget Constraints

$$\sum_i \sum_j (f_{ij} c_{ij}) x_{ij} d_{ij} + \sum_i \sum_j (Cr_{ij} x_{ij}) \leq max * d_{ij} * sales\ price \quad (7)$$

(vi) Assignment Constraints

$$\sum_i \sum_j x_{ij} = 1, \qquad \forall i \in I \quad (8)$$

(vii) Precedence Constraints

$$\sum_i \sum_j j x_{hj} \leq \sum_i \sum_j j x_{ij}, \qquad \forall i \in I, h, i, j \in I \quad (9)$$

The assignment of tasks to workers of multi-manned workstations must follow the precedence constraints of the problem. Task *i* can be assigned to worker *k* of multi-manned workstation *j*, when all of its predecessors like *h* are assigned to prior workstations. The precedence constraint (Eq. 9) ensures that all such precedence relationships for all models are satisfied.

(viii) Area Constraints

$$\sum_{i \Rightarrow m} a_i \leq A_m \quad (10)$$

(ix) Non-Negativity Constraints
All of the variables are nonnegative. The objective function sums up the cost terms which relates to the activities and location pairs. The movement cost, $c_{ikj}h$, is added to the total cost only if activities *i* and *j* are indeed assigned to locations *k* and *h* and x_{ik} and x_{jh} are both positive. The first set of constraints ensures that each location will have exactly one activity assigned to it, while the second guarantees that each activity is assigned to exactly one location. The upshot of both sets of constraints is that each activity is assigned the exclusive use of one location, which is what is necessary for the solution to be valid.

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4. Improved Simulated Annealing Approach

Simulated annealing is a combinatorial optimization algorithm. Kirkpatrick et al. (1983) firstly introduced and Eglese (1990) used and applied to with local search algorithm in operations research. The algorithm obtained and simulated the cooling of a mass of vibrating atoms from a high temperature *T*. According to Ligget (2000) the probability of acceptance (*p*) of the replace of a pair of activities equals one when the replace offers a better value of the objective function. When the cost change is positive (i.e., increases the cost), the probability of acceptance *p* is a function of the diversity of the values in objective function for the current solution and the new solution (Δ), and an additional control parameter, *T* (which represents temperature in the actual annealing process):

$$p=(exp(-\varDelta/T)) \tag{11}$$

In general, the lower temperature *T* provides the little of the chances for the acceptance of a new solution. During execution of the algorithm, the temperature of the system, *T*, is lowered in steps. When the *T* reaches to zero, the algorithm terminates and obtained the optimum value. The suggested below algorithm adapted from Rardin (2000).

Step 0: Initialization: Choose randomly any starting feasible solution $x^{(0)}$, an iteration limit t_{max}, and a relatively large initial temperature $q>0$. Then set incumbent solution $\hat{x} \leftarrow x^{(0)}$ and solution index $t \leftarrow 0$.x represents the each nodes (facility options).

Step 1: Stopping: If no move $\varDelta x$ in move set M leads to a feasible neighbor of current solution $x^{(t)}$, or if $t= t_{max}$, then stop. Incumbent solution $\hat{x}$ is an approximate optimum.

Step 2: Provisional Move: Randomly choose a feasible move $\varDelta x \in M$ as aprovisional $\varDelta x^{(t+1)}$, and compute the (possibly negative) net objective function improvement $\varDelta$ obj for moving from $x^{(t)}$ to $(x^{(t)}+\varDelta x^{(t+1)})$.

If there are no inbound arcs at node *p*, set $v[p] \leftarrow \infty$. Otherwise, compute

$$x^{(t)} \leftarrow \min\{x^{(t)}+Ci,p\text{: } (i,p) \text{ exists}\}. \text{ Then return to Step 0.}$$

Step 3: Acceptance: If $\varDelta x^{(t+1)}$ improves, or with probability $e^{\varDelta obj/q}$ if $\varDelta obj \leq 0$, accept $\varDelta x^{(t+1)}$ and update.

$$x^{(t+1)} \leftarrow x^{(t)}+\varDelta x^{(t+1)}$$

Otherwise, return to Step 2.

Step 4: Incumbent Solution: If the objective function value of $x^{(t+1)}$ is superior to that of incumbent solution $\hat{x}$, replace $\hat{x} \leftarrow x^{(t+1)}$.

Step 5: Temperature Reduction: If a sufficient number of iterations have passed since the last temperature change, reduce temperature q.

Step 6: Increment: Increment $t \leftarrow t+1$, and return to Step1.

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5. Application

Singh and Singh (2010) proposed three stage heuristic approach for solving MOFLP. Our suggested heuristic approach includes the three main steps which are: (a) data matrix of each objective is normalized; (b) entropy based approach used the computation of the objective weight; and (c) MOFLP is solved with linear programming and multi-objective simulated annealing approach for n=9. An improved simulated annealing for multi objective facility layout problem.

In this section, facility location and among of the relations are considered. The related factors are given in below. Fig.1 represents the each facility layout situations. These parameters are used in the our facility layout design with evaluation criteria.

Once objective weights have been calculated, the MOFLP is solved as single objective FLP considering the original objective matrixes. For this purpose, modified SA algorithm is used. An initial feasible solution A is generated. For obtaining an initial solution A the facilities are allotted to locations in a sequential manner such that facility 1 is in location 1, facility 2 is in location 2 and so on. The composite relationship and the distance matrix for the initial configuration form considered as the other inputs to the program. From the above the combined objective function value (Z) is computed using Eq. (1).

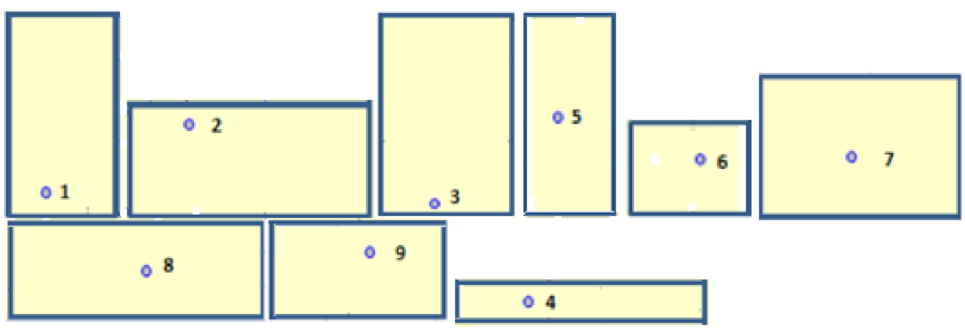

Fig. 1. Facility layouts

Table 1. Facilities and location coordinations

Facility No	X	Y
F1	53,1075	7,7266
F2	87,6740	72,6670
F3	74,43245	5,153024
F4	86,19077	79,72915
F5	20,40916	40,73364
F6	33,91671	48,14801
F7	55,36254	90,24361
F8	97,27642	97,39993
F9	64,61363	66,46982

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Table 1 represents the facilities and location coordinations. Table 2 represents the distance matrix of the facilities. Euclidean distance parameters used to find among of the facilities distance value. Fig. 2 shows the sample facility layout design for F1-F5-F6-F9-F7-F8-F4-F2-F3.

Table 2. Distance matrix of the facilities

Facility No	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1		73,567	21,47973	79,23931	46,46118	44,74565	82,54779	99,96098	59,85946
F2			68,80029	7,216212	74,46009	59,08496	36,78273	26,53153	23,8786
F3				75,4974	64,68768	59,07702	87,20132	95,03335	62,09798
F4					76,47137	61,07328	32,57197	20,8602	25,32553
F5						15,40866	60,60509	95,49683	51,15063
F6							47,24366	80,25088	35,74899
F7								42,52042	25,51031
F8									44,98365
F9									

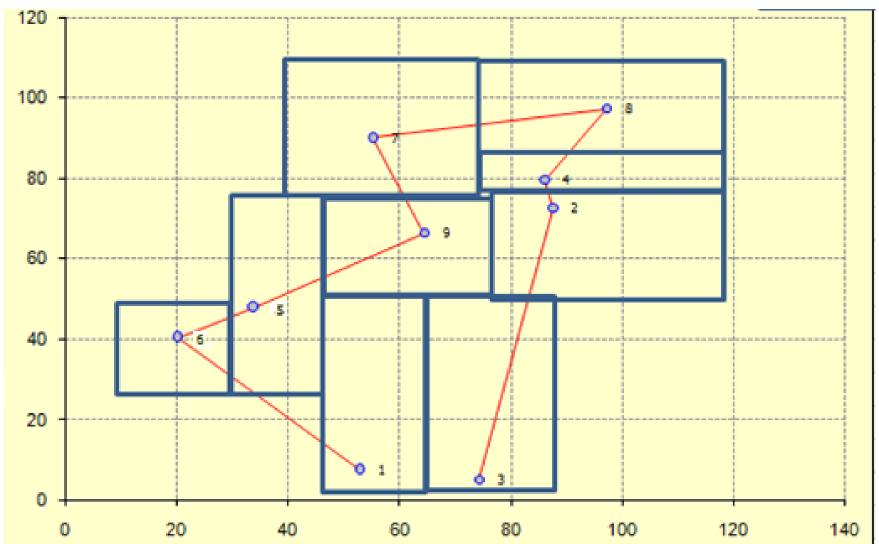

Fig. 2. Sample facility layout design

The performance evaluation considers the *n*=9 unequal facility layout heuristic problem size. The improves SA heuristic problem strucure uses the whole multi objective function elements. Which are material handling cost, remoteness fuction, using of the area, reconfiguration cost and suitably between departments and locations. In the litearaure Rosenblatt (1986), Chen and Sha (2005) consider the work flow and closeness rating objectives. Fortenberry and Cox (1985) analyzed the facility layout problems with multi criteria decision making approach. Also Torkul et al. (2013) used the fuzzy grey relation aprroach to analysis of the facility layout design problem parameters. Singh and Singh (2010) demonstrated the effectiveness of proposed modified SA. Our suggetsed algorithm includes the below steps:

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Step 1: Matrix Normalization
This stage normalized the objective function's parameters which are the material handling cost, remoteness fuction, using of the area, reconfiguration cost and suitably between departments and locations matrix.

Step 2: Objective Weight Computation
In the second stage, relative weight of each objective is determined with using of the entropy. Material handling cost, remoteness fuction, using of the area, reconfiguration cost and suitably between departments and locations matrix. The weight function values are obtained from Shannon's entropy rule which are α=0.4871 (weight for material handling cost, β=0.1207 (weight for remoteness function), θ=0.0946 (weight for using of the area), δ=0.0858 (weight for reconfiguration cost) and φ=0.1285 (weight for suitably between departments and location matrix). The Entropy is

$$\tilde{E}_j = -k\sum_{i-1}^{n} e_{ij} Ine_{ij}. = -\frac{1}{Inm}\sum_{i-1}^{n} e_{ij} In\, e_{ij} \tag{12}$$

In the final step, MOFLP is solved with using proposed modified SA in this paper. The objective function main parameters are listed in Table 3 and calculated parameters are expressed in Table 5. Also Table 4 shows the remoteness function value among the facilities. Table 6 represents the using of the area. Reconfiguration costs are given in Table 7. Suitable situations among the facilities (0-represents the negative situation, 1 represents the positive situation) in Table 8. The objective values obtained and given in the Table 9.

Table 3. Cost coefficients

	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1		0,05	0,1	0,1	0,11	0,15	0,14	0,15	0,2
F2			0,2	0,15	0,1	0,1	0,15	0,1	0,2
F3				0,16	0,1	0,16	0,22	0,18	0,18
F4					0,22	0,18	0,25	0,15	0,2
F5						0,2	0,15	0,16	0,12
F6							0,12	0,15	0,1
F7								0,1	0,2
F8									0,2
F9									

Table 4. Remoteness function value among the facilities

	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1		0,1	0,2	0,3	0,1	0,2	0,3	0,2	0,3
F2			0,3	0,2	0,2	0,3	0,4	0,3	0,2
F3				0,2	0,3	0,3	0,2	0,2	0,1
F4					0,2	0,1	0,3	0,4	0,4
F5						0,4	0,3	0,2	0,2
F6							0,3	0,4	0,2
F7								0,2	0,3
F8									0,3
F9									

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Table 5. Calculated of the objective function parameters

Alternatives	1	2	3	4	5	6	7	8	9	Material Handling Cost	Remoteness Function Value	Cost Coefficients
1	7	6	8	9	1	2	3	4	5	526,673703	2,1	1,3
2	8	7	9	1	2	3	4	5	6	437,634894	2	1,33
3	7	6	5	8	9	1	2	3	4	480,856938	2,1	1,29
4	8	7	6	9	1	2	3	4	5	479,708578	1,8	1,15
5	9	8	7	1	2	3	4	5	6	479,796568	2	1,27
6	7	5	6	4	8	9	1	2	3	405,157625	1,9	1,13
7	1	8	9	7	2	3	4	5	6	443,415377	2	1,28
8	7	3	4	5	6	2	8	9	1	445,038338	2,2	1,4
9	7	2	3	4	5	6	1	8	9	462,650716	2,2	1,43
10	4	8	9	1	2	3	7	5	6	431,285662	2,3	1,37
11	6	9	1	2	3	4	5	8	7	527,961744	1,7	1,19
12	7	1	2	3	4	5	6	9	8	473,025138	2	1,27
13	6	8	9	1	2	3	4	5	7	540,03513	2,1	1,33
14	7	9	1	2	3	4	5	6	8	490,611302	2	1,39
15	5	7	6	8	9	1	2	3	4	510,807425	2,2	1,23
16	6	8	7	9	1	2	3	4	5	502,47712	2	1,28
17	7	9	8	1	2	3	4	5	6	480,199643	2	1,38
…	…	…	…	…	…	…	…	…	…	498,734039	1,8	1,09
66	7	8	9	1	2	3	6	5	4	440,687863	2,1	1,33
67	9	1	2	3	4	5	8	7	6	449,855051	1,9	1,18
68	9	1	2	3	4	5	6	8	7	492,37547	2,1	1,28

Table 6. Using of the area

Facilities	Using of area(%)
F1	80%
F2	90%
F3	60%
F4	88%
F5	95%
F6	90%
F7	85%
F8	96%
F9	99%

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Table 7. Reconfiguration cost

Facilities	Reconfiguration Cost
F1	88000
F2	92000
F3	50000
F4	25000
F5	45000
F6	20000
F7	15000
F8	18000
F9	20000

Table 8. Suitable situations among the facilities (0-represents the negative situation, 1 represents the positive situation)

	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1	-	1	0	0	1	1	0	1	1
F2		-	1	0	1	1	0	0	1
F3			-	1	0	0	1	0	0
F4				-	1	1	0	1	1
F5					-	1	0	1	0
F6						-	0	1	0
F7							-	0	1
F8								-	1
F9									-

MOFLP of size n=9 is solved using proposed three step approach in this paper and objective weights, objective function value and feasible layout plans are given in Table 9.

Table 9. Computational results

Alternatives	F1	F2	F3	F4	F5	F6	F7	F8	F9	Material Handling Cost	Normalized Cost Value	Remoteness Function Value	Cost Coefficients	InIncumbent	Temp q	□ Object	DECISION
1	7	6	8	9	1	2	3	4	5	526,673703	3,4178	2,1	1,3	2,27	5	0,22	REJECT
2	8	7	9	1	2	3	4	5	6	437,634894	2,84	2	1,33	2,06	5	-0,11	ACCEPT
3	7	6	5	8	9	1	2	3	4	480,856938	3,1205	2,1	1,29	2,17	5	0,15	REJECT
4	8	7	6	9	1	2	3	4	5	479,708578	3,1131	1,8	1,15	2,02	5	-0,11	REJECT
5	9	8	7	1	2	3	4	5	6	479,796568	3,1136	2	1,27	2,13	5	0,24	REJECT
6	7	5	6	4	8	9	1	2	3	405,157625	2,6293	1,9	1,13	1,89	5	-0,17	ACCEPT
7	1	8	9	7	2	3	4	5	6	443,415377	2,8775	2	1,28	2,05	5	-0,11	ACCEPT
8	7	3	4	5	6	2	8	9	1	445,038338	2,8881	2,2	1,4	2,16	5	-0,05	REJECT
9	7	2	3	4	5	6	1	8	9	462,650716	3,0024	2,2	1,43	2,21	5	0,05	REJECT
10	4	8	9	1	2	3	7	5	6	431,285662	2,7988	2,3	1,37	2,16	5	0,05	ACCEPT
11	6	9	1	2	3	4	5	8	7	527,961744	3,4262	1,7	1,19	2,11	5	-0,01	REJECT
12	7	1	2	3	4	5	6	9	8	473,025138	3,0697	2	1,27	2,11	5	-0,2	REJECT
13	6	8	9	1	2	3	4	5	7	540,03513	3,5046	2,1	1,33	2,31	5	0,12	REJECT
14	7	9	1	2	3	4	5	6	8	490,611302	3,1838	2	1,39	2,19	5	-0,06	REJECT
15	5	7	6	8	9	1	2	3	4	510,807425	3,3149	2,2	1,23	2,25	5	0,07	REJECT
16	6	8	7	9	1	2	3	4	5	502,47712	3,2608	2	1,28	2,18	5	0,01	REJECT
17	7	9	8	1	2	3	4	5	6	480,199643	3,1163	2	1,38	2,17	5	0,12	REJECT
18	5	8	7	6	9	1	2	3	4	498,734039	3,2365	1,8	1,09	2,04	5	-0,03	REJECT
19	6	9	8	7	1	2	3	4	5	500,136899	3,2456	1,8	1,17	2,07	5	-0,14	REJECT
20	7	1	9	8	2	3	4	5	6	450,100136	2,9209	2,3	1,42	2,21	5	0,15	REJECT
21	3	7	5	6	4	8	9	1	2	423,558651	2,7487	2,1	1,35	2,07	5	-0,09	REJECT
22	6	1	8	9	7	2	3	4	5	482,991046	3,1344	2	1,33	2,15	5	-0,08	REJECT
23	7	2	9	1	8	3	4	5	6	482,892537	3,1337	2,1	1,46	2,23	5	0	REJECT
24	2	7	4	5	6	3	8	9	1	420,188209	2,7268	2,4	1,56	2,23	5	0,21	ACCEPT
25	7	3	9	1	2	8	4	5	6	421,997507	2,7386	2	1,32	2,02	5	-0,2	ACCEPT
26	7	4	9	1	2	3	8	5	6	466,063084	3,0245	2,2	1,44	2,22	5	0,07	REJECT
27	6	4	8	9	1	2	3	7	5	476,950285	3,0952	2	1,35	2,15	5	-0,04	REJECT
28	7	5	9	1	2	3	4	8	6	490,590945	3,1837	2,2	1,18	2,19	5	0,06	REJECT
29	8	6	1	2	3	4	5	9	7	495,993519	3,2187	1,9	1,25	2,12	5	-0,05	REJECT
30	9	7	2	3	4	5	6	1	8	443,177374	2,876	2,2	1,43	2,17	5	0,01	ACCEPT
31	7	6	9	1	2	3	4	5	8	532,684986	3,4569	1,8	1,21	2,16	5	0,11	REJECT
32	8	7	1	2	3	4	5	6	9	470,561908	3,0537	1,9	1,17	2,04	5	-0,23	REJECT
33	4	5	7	6	8	9	1	2	3	511,781395	3,3212	2,2	1,29	2,27	5	0,16	REJECT
34	5	6	8	7	9	1	2	3	4	441,414412	2,8646	2,2	1,26	2,11	5	-0,07	ACCEPT

35	6	7	9	8	1	2	3	4	5	512,034645	3,3228	1,9	1,3	2,17	5	0,11	REJECT
36	4	5	8	7	6	9	1	2	3	499,708009	3,2429	1,8	1,15	2,06	5	0,06	REJECT
37	5	6	9	8	7	1	2	3	4	439,074191	2,8494	2	1,15	2	5	-0,17	ACCEPT
38	2	3	7	5	6	4	8	9	1	418,791946	2,7178	2,3	1,5	2,17	5	0,05	ACCEPT
39	5	6	1	8	9	7	2	3	4	411,689657	2,6717	2,3	1,41	2,13	5	0,03	ACCEPT
40	5	6	4	8	9	1	2	3	7	431,753855	2,8019	2,1	1,4	2,1	5	0	ACCEPT
41	8	9	7	2	3	4	5	6	1	388,200048	2,5192	2,3	1,48	2,1	5	-0,14	ACCEPT
42	3	4	5	7	6	8	9	1	2	518,478499	3,3647	2,1	1,25	2,24	5	0,11	REJECT
43	4	5	6	8	7	9	1	2	3	442,388382	2,8709	2,2	1,32	2,13	5	0,01	ACCEPT
44	3	4	5	8	7	6	9	1	2	524,489782	3,4037	1,8	1,16	2,12	5	0,1	REJECT
45	4	5	6	9	8	7	1	2	3	440,048161	2,8557	2	1,21	2,02	5	-0,06	ACCEPT
46	1	2	3	7	5	6	4	8	9	432,499487	2,8067	2,1	1,35	2,09	5	-0,02	ACCEPT
47	4	5	6	1	8	9	7	2	3	422,902309	2,7444	2,2	1,37	2,1	5	-0,24	ACCEPT
48	2	3	4	5	7	6	8	9	1	513,711793	3,3337	2,3	1,4	2,34	5	0,25	REJECT
49	3	4	5	6	8	7	9	1	2	449,085486	2,9143	2,1	1,28	2,1	5	0,16	ACCEPT
50	2	3	4	5	8	7	6	9	1	444,156065	2,8824	1,7	1,24	1,94	5	-0,05	ACCEPT
51	3	4	5	6	9	8	7	1	2	446,745265	2,8992	1,9	1,17	1,99	5	-0,08	REJECT
52	3	4	5	6	1	8	9	7	2	429,599413	2,7879	2,1	1,33	2,07	5	-0,09	ACCEPT
53	8	9	1	2	6	4	5	3	7	526,928713	3,4195	1,8	1,27	2,16	5	0,05	REJECT
54	9	1	2	3	7	5	6	4	8	447,375294	2,9032	2,1	1,35	2,12	5	-0,09	ACCEPT
55	2	3	4	5	6	8	7	9	1	444,31878	2,8834	2,3	1,43	2,2	5	0,25	ACCEPT
56	1	2	3	4	5	8	7	6	9	440,709322	2,86	1,9	1,1	1,95	5	-0,14	ACCEPT
57	2	3	4	5	6	9	8	7	1	441,978559	2,8682	2,1	1,32	2,1	5	-0,07	ACCEPT
58	2	3	4	5	6	1	8	9	7	451,378291	2,9292	2,1	1,48	2,17	5	0,14	REJECT
59	7	8	9	1	2	6	4	5	3	482,247814	3,1295	1,8	1,15	2,03	5	-0,13	REJECT
60	8	9	1	2	3	7	5	6	4	471,498743	3,0598	2	1,4	2,15	5	0,04	REJECT
61	1	2	3	4	5	6	8	7	9	458,026321	2,9724	2,1	1,28	2,12	5	0,04	ACCEPT
62	7	8	9	1	2	3	5	4	6	491,963142	3,1926	1,8	1,25	2,08	5	-0,03	REJECT
63	8	9	1	2	3	4	6	5	7	459,79482	2,9838	2	1,34	2,11	5	-0,18	REJECT
64	9	1	2	3	4	5	7	6	8	542,295142	3,5192	2,1	1,25	2,29	5	0,31	REJECT
65	1	2	3	4	5	6	9	8	7	432,997769	2,8099	1,9	1,23	1,98	5	-0,12	REJECT
66	7	8	9	1	2	3	6	5	4	440,687863	2,8598	2,1	1,33	2,1	5	0,1	ACCEPT
67	9	1	2	3	4	5	8	7	6	449,855051	2,9193	1,9	1,18	2	5	-0,19	ACCEPT
68	9	1	2	3	4	5	6	8	7	492,37547	3,1953	2,1	1,28	2,19	5	2,19	REJECT

6. Conclusions and Future Studies

This chapter suggests a new multi objective simulated annealing for unequal area facility layout design problems. The relative function represented the normalized matric and evaluated with entropy weight functions. Facility Layout Problem (FLP) is defined as the problem of locating facilities in a limited area such that associated layout costs are minimized. Layout costs arise from various sources including material handling, time, and slack area.

The purpose of the study was to determine highest system performance design of the facility layout. It has been aimed to find most proper design with minimum cost that used of the alternative facility layout plans.

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