13th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

A META-HEURISTIC APPROACH FOR THE FACILITY LAYOUT DESIGN PROBLEM

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ABSTRACT
In this paper, facility layout problem is investigated. Since facility layout problems belong to NP-hard problems group, a meta-heuristic, Simulated Annealing is proposed to solve the problem. Simulated Annealing is preferred because of its capability of jumping out of the local optima for global optimization. Also, an application is given to foster the better understanding of the methodology.
Keywords: facility layout design, simulated annealing, meta-heuristics

1. INTRODUCTION
One of the most important problems encountered in both the manufacturing and service industry is the determination of department locations in a facility, that is, determination of the optimal shape and the location of a set of departments. Each department has own area constraints, shape limitations and different levels of interactions with the other departments. Determining of the physical organization of a facility is defined to be the facility layout problem (FLP). Essentially, the FLP is concerned with finding the most efficient non-overlapping arrangement of interacting departments with equal or unequal area requirements within a facility [1]. The efficiency of the facility layout is typically measured in terms of the material handling costs [2]. Minimizing the material handling costs and maximizing the adjacency requirements are the main considered objectives but also additional qualitative and quantitative objectives are given. Reducing the total cost of transporting materials and maximizing the adjacency requirements result in reduced work-in-process levels, throughput times, product damage and simplified material control and scheduling, simultaneously [3]. The output of the FLP is a block layout, which specifies the relative location of each department [4]. Various models and solution methodologies for the FLP have been developed during the past four decades. Most of them have been based on a quadratic assignment problem (QAP), linear integer programming problem, mixed integer programming problem or graph-theoretic problem [5; 6]. The QAP is NP-hard [7], which implies that it is a hard problem to solve generally, and cannot be solved optimally for more than 15-20 departments because its computational time is exponentially increased. Similarly, other methodologies mentioned above are unsolvable for any realistic-sized applications and require high computational time as the problem size increases. Furthermore, there is no any algorithm for solving these kinds of FLP problems in polynomial time and most of the real world problems may require long computational time [8]. Hence, these types of problems belong to non-polynomial hard (NP-hard) problems. Therefore, a number of heuristics and meta-heuristics algorithms have been developed to seek near optimal solutions at reasonable computational time for large-scaled problems. Heuristics are usually utilized in solving the NP-hard problems. Various heuristics which are popular as layout software such as CRAFT [9], ALDEP [10], CORELAP [11], COFAD [12], SPIRAL [13], MULTIPLE [14] etc. have been developed by different researchers. A recently detailed survey on the FLP and its solution approaches can be found in [3]. Furthermore, different meta-heuristics such as simulated

annealing (SA), tabu search (TS), genetic algorithm (GA) and ant colony are currently used to solve the NP-hard and large FLPs. In this paper, we focused on the application of SA and GA and the hybridization of them to a FLP problem with single floor. These meta-heuristics have been used to solve a wide variety of FLPs individually [15; 16; 17; 18; 19]. A detailed literature review for before 2003 can be found in [3].

In this study, a SA approach is utilized to solve the facility layout problem. In the next section, a brief overview SA is given. In the third section, an example application is solved as an illustrative example. In the final section, conclusions are given.

2. SIMULATED ANNEALING

SA was first proposed by [20] to solve combinatorial problems in the early 1980s. It has the capability of jumping out of the local optima for global optimization. The capability is achieved by accepting with probability neighboring solutions worse than the current solution. The acceptance probability is determined by a control parameter (temperature) which decreases during the SA procedure [21].

3. APPLICATION

In this section, an example application is presented with 19 different departments. These departments and the material flows between them are given in Table 1.

Table 1. The departments and the flows between the departments

Depar. #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
1	0	2795	0	167,5	0	840	0	120	0	0	0	0	0	0	0	20	0	0	0
2		0	1970	0	0	0	0	0	175	40	575	0	0	0	80	0	0	0	0
3			0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4				0	0	0	0	0	0	115	0	0	0	0	40	0	0	0	0
5					0	0	550	0	55	0	250	0	0	0	0	0	200	0	0
6						0	0	0	40	0	150	0	0	0	0	0	50	0	0
7							0	0	0	0	550	0	0	0	0	0	0	0	0
8								0	120	0	0	0	0	0	40	0	0	0	0
9									0	0	0	0	175	0	0	0	0	0	0
10										0	0	0	0	0	40	0	0	0	0
11											0	800	0	0	0	0	0	0	0
12												0	0	2	0	0	200	798	0
13													0	2	0	0	0	173	0
14														0	0	0	0	0	0
15															0	40	0	40	0
16																0	0	40	0
17																	0	0	0
18																		0	895
19																			0

Considering the aim of obtaining only a starting layout solution and providing the simplicity, the area requirements of the departments are assumed to be equal instead of the real shapes and sizes. At the end of this solution procedure the relative positions of the equal sized departments will be obtained to further improvements of the planners. An example layout of the locations and the chromosome representation of the department locations are given in the Table 2 and Figure 1.

Table 2. An example chromosome representation of the department locations

Location number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Department number	15	2	4	8	11	16	1	6	7	12	9	19	10	3	17	13	5	18	14

$15_{(0)}$	$2_{(1)}$	$4_{(2)}$	$8_{(3)}$	$11_{(4)}$
$16_{(5)}$	$1_{(6)}$	$6_{(7)}$	$7_{(8)}$	$12_{(9)}$
$9_{(10)}$	$19_{(11)}$	$10_{(12)}$	$3_{(13)}$	$17_{(14)}$
$13_{(15)}$	$5_{(16)}$	$18_{(17)}$	$14_{(18)}$	

Figure 1. The locations representation of the chromosome given in the Table 2 ($n_{(i)}$; n = department number, i = location number).

The distances between the locations are calculated as the sum of the vertical and horizontal movements between the centers of the departments. It is assumed that the diagonal ways are not allowable. For example, we can see from Figure 1 that the distance between department 15 (in location 0) and department 10 (in location 2) is two horizontal movements and two vertical movements. Thus the distance between two locations= 2+2=4.

As mentioned above, the data used in the problem is related with the flows between the departments and the distances of the sites that departments will be assigned to them. Also the other data type is the penalty values determined considering with the qualitative relationships between the departments. These qualitative requirements are transformed to quantitative values by using the distances. For example, if two specific departments which have to be close to each other depending on their relationship importance are not close, then the distance between them is multiplied with a constant penalty value like as Tuzkaya *et al.* [22].

In this study, two objective functions: minimizing the total material handling cost and minimizing the total penalty values are considered based on the research of Tuzkaya *et al.* [22] . The first objective is satisfied by putting closer the departments which have intensive material flows between each other. The second objective function is satisfied by minimizing the penalty values which are constituted by putting any two departments close to each other that cannot be near each other. A constant penalty value is multiplied by "1/distance" value of determined departments. The relationships of not being adjacent departments are related with the quality and safety necessities. In this study, there are some departments which have a bad affect on the others. For example, since wet painting department have some combustible materials, it should not be adjacent with the welding and drilling department that causes to produce spark parts. Also, final product warehouse and grinding departments should not be adjacent since final product's quality may be affected negatively from a situation like this. Considering the intensity of these relationships, constant penalty values are assigned to the above mentioned departments and to additional ones as shown in Table 3. For example, as it is seen from the Table 4, if department 1 and department 7 are located as adjacent departments, a penalty value of 300*1/1 will be added to the fitness function. If department 1 and 7's distance is 2 units, the penalty value will be 300*1/2. With the increases of the distances between these two departments, the penalty values will be decreased.

Table 3. The assigned penalty values to the department pairs according to the adjacency relationships

Department Pairs	2-8	11-4	11-6	13-4	13-6	13-7	14-4	14-6	14-7	15-4	15-6	15-7	19-6
Penalty values	300	3000	3000	150	150	150	150	150	150	150	150	150	600

In this study, to find a more appropriate facility layout solution for the company, SA approach is utilized and the operators of it is given in Table 4.

Table 4. The operators of SA

Population size	1
Process length	98 iterations
Initial temperature	1500 ºC
Final temperature	10 ºC
Cooling factor	0.95
K Adjustment Coefficient	1
Neighborhood mechanism	Pair wise interchanges between neighborhoods

Finally, the problem is solved via SA methodology for a hundred runs and best solution obtained is given in Figure 2. In this solution, the final chromosome is (13, 8, 3, 5, 2, 11, 1, 9, 14, 15, 6, 7, 12, 0, 10, 18, 4, 17, 16), the fitness value is 18664,02 unit and the departments are arranged as Figure 2.

$14_{(0)}$	$9_{(1)}$	$4_{(2)}$	$6_{(3)}$	$3_{(4)}$
$12_{(5)}$	$2_{(6)}$	$10_{(7)}$	$15_{(8)}$	$16_{(9)}$
$7_{(10)}$	$8_{(11)}$	$13_{(12)}$	$1_{(13)}$	$11_{(14)}$
$19_{(15)}$	$5_{(16)}$	$18_{(17)}$	$17_{(18)}$	

Figure 2. Departments' arrangements for SA

4. CONCLUSIONS

In this study, a Simulated Annealing methodology is utilized to solve the facility layout design problem. Simulated Annealing is an effective meta-heuristics with its capability of jumping out of the local optima for global optimization. Also, an application of the proposed methodology is presented to foster the better understanding of the methodology. For future research, benchmarking of the proposed methodology may be realized with test problems presented in the literature of facility layout design problem. Also comparison with the other meta-heuristics of the Simulated Annealing approach may be studied.

5. REFERENCES

[1] Bozer YA, Meller RD, Erlabacher SJ (1994) An improvement type layout algorithm for single and multiple-floor facilities. Management Science 40(7):918-932.

[2] Liu Q, Meller RD (2007) A sequence-pair representation and MIP-model-based heuristic for the facility layout problem with rectangular departments. IIE Transactions 39:377-394.

[3] Singh SP, Sharma RRK (2006) A review of different approaches to the facility layout problems. International Journal of Advanced Manufacturing Technology 30:425-433.

[4] Meller RD, Gau KY (1996) The facility layout problem: Recent and emerging trends and perspectives. Journal of Manufacturing Systems 15:351-366.

[5] Montreuil B (1990) A modeling framework for integrating layout design and flow network design. Proceedings from the Material Handling Research Colloquium, Hebron KY:43-58.

[6] Heragu S, Kusiak A (1991) Efficient models for the facility layout problems. European Journal of Operations Research 53:1-13.

[7] Garey MR, Johnson DS (1979) Computers and intractability: a guide to theory of NP-completeness. WH Freemen, New York.

[8] Kusiak, A. and Heragu, S. S. (1987) The facility layout problem. European Journal of Operational Research, 29: 229-251.

[9] Armour GC, Buffa ES (1963) A heuristic algorithm and simulation approach to relative allocation of facilities. Management Science 9:294-309.

[10] Seehof JM, Evans WO (1967) Automated layout design program. Journal of Industrial Engineering 18:69-695.

[11] Lee R, Moore JM (1967) CORELAP-computerized relationship layout planning. Journal of Industrial Engineering 18(3):195-200.

[12] Tompkins JA, Reed RJ (1976) An applied for the facilities design problem. International Journal of Production Research 14(5):583-595.

[13] Goetschalckx M (1992) An interactive layout heuristic based on hexagonal adjacency graphs. European Journal of Operations Research 63:304-321.

[14] Bozer YA, Meller RD, Erlabacher SJ (1994) An improvement type layout algorithm for single and multiple-floor facilities. Management Science 40(7):918-932.

[15] Hu MH, Wang MJ (2004) Using genetic algorithms on facilities layout problems. International Journal of Advanced Manufacturing Technology 23:301-310.

[16] Wang MJ, Hu MH, Ku MY (2005) A solution to the unequal area facilities layout problem by genetic algorithm. Computers in Industry 56:207-220.

[17] Aiello G, Enea M, Galante G (2006) A multi-objective approach to facility layout problem by genetic search algorithm and Electre method. Robotics and Computer-Integrated Manufacturing 22:447-455.

[18] Norman BA, Smith AE (2006) A continuous approach to considering uncertainty in facility design. Computers & Operations Research 33(6):1760-1775.

[19] McKendall AR, Shang J, Kuppusamy S (2006) Simulated annealing heuristics for the dynamic facility layout problem. Computers & Operations Research 33(8): 2431-2444.

[20] Kirpatrck E. (1984) Optimization by simulated annealing-quantitative studies. Journal of Statistical Physics. v34. 975-986.

[21] Seckiner A U, Kurt M (2007) A Simulated annealing approach to the solution of job rotation scheduling problems. Applied Mathematics and Computation, 188(1): 31-45.

[22] Tuzkaya UR, Ertay T and Ruan D (2005) Simulated Annealing Approach for the Multi-objective Facility Layout Problem. Intelligent Data Mining: Techniques and Applications, Springer-Verlag New York Inc.