International Journal of Applied Operational Research
Vol. 1, No. 3, pp. 1-9, Winter 2011

Journal homepage: www.ijorlu.ir

Applying Genetic Algorithm to Dynamic Layout Problem

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Received: June 13, 2011 ; **Accepted:** September 4, 2011

Abstract In today's economy, manufacturing plants must be able to operate efficiently and respond quickly to changes in the product mix and demand.[1] Layout design has a significant impact on manufacturing efficiency. Initially, it was treated as a static decision but due to improvements in technology, it is possible to rearrange the manufacturing facilities in different scenarios. The Plant layout affects on the total cost in the industry. Nowadays Dynamic layout is becoming an important issue. Dynamic layout is the different layout at different time periods to satisfy the needs of industry; due to change in product, or reduced product life cycle, or change in demand. Layout problem is a quadratic assignment problem, and for larger size problems it becomes impossible to be solved. So, for solving this problem Meta heuristic algorithms are used. In this paper, Dynamic layout problem is solved using Genetic algorithm. This Dynamic Problem is restricted up to two-time periods only.

Keywords Dynamic Layout, Heuristics, Genetic Algorithm.

1 Introduction

Layout design invariably has a significant impact on the performance of a manufacturing or service industry system, and consequently has been an active research area for several decades. The layout design problem is a complex problem involving issues related to processes, machines, handling equipments, manpower, space utilization, safety etc. Much of the existing layout design literature that uses a surrogate function for flow distance or for simplified objectives may be entrapped into local optimum; and subsequently lead to a poor layout design due to the multiple-attribute decision making (MADM) nature of a layout design decision. [1].When the flow of materials between the departments is fixed during the planning horizon, this problem is known as the static (single period) facility layout problem (SFLP), which can be formulated as a quadratic assignment problem (QAP). The SFLP literature is reviewed in detail by Meller and Gau [2]. When the flow of materials between departments changes during the planning horizon, this problem is known as the dynamic (multiple period) facility layout problem (DFLP). Some of the factors associated with changes in the flow between departments are changes in the design of an existing product, the addition or deletion of a product, replacement of existing production equipment, shorter product life cycles, changes in the production quantities and associated production schedule [3].

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The application of new optimization techniques provides a perspective of the future research in Dynamic facility layout problems and hybrid algorithm [4]. Different meta-heuristics such as simulated annealing (SA), genetic algorithm (GA), Tabu Search, Ant Colony are used to solve such problems by different authors. This paper aims to deal with the application of Genetic Algorithm to solve the Dynamic plant layout problem. A Virtual problem is considered in this paper. A trend toward multi-objective approaches is also handled in this paper.

This paper is organized as follows; Section 2 provides a brief review of the literature, on the Optimization of Plant Layout problem. Optimization techniques are discussed in Section 3, and section 4, discuses the formulation for Facility Layout Problem. In section 5, a virtual problem is considered with flow, cost and relationship constraints and also with dynamic concept. In section 6, the results are discussed and section 7 deals with conclusion.

2 Literature review

Tompkins and White estimated that 8% of the United States gross national product has been spent on new facilities annually since 1955, which does not include the modification of existing facilities. Francis and White [5] claimed that from 20 to 50 percent of the total operating expenses in manufacturing are attributed to materials handling costs. Effective facilities planning could reduce these costs by 10 to 30 percent annually.

A review of literature shows that plant layout is affected by multiple factors and it has to be treated as a multi-objective optimization problem. Traditionally, layout planning was treated as a strategic decision, which once implemented was difficult to modify. Availability of modern machine tools has changed the perspective of layout planning. A combination (Hybrid) of various algorithms for optimization at various stages of layout planning and implementation will be useful in getting the effective performance. There is also a need to develop new optimization techniques for comparing the alternate layout proposals in the present context. This can be done with the help of hybrid algorithm.

Long time back Rosenblatt has discussed about the modeling of dynamic facility layout problem (DFLP). Since then, there have been improvements to Rosenblatt’s original dynamic programming model [2]. Islier, presented a genetic algorithm-based model for facility layout. Bozeri and Meller, considered the distance-based facility layout problem. Mckendall described the nested facility layout problem for irregular-shaped departments. Lacksonen, studied dynamic facilities layout problem while permitting the departments to have unequal areas. Branch and bound algorithm was used to find good feasible solution. Deb and Bhattacharyya presented a distinct methodology for the facility layout process using a fuzzy decision-making system for handling inexact / vague data. Deb and Bhattacharyya, Proposed a hybrid heuristic model for integrating plant layout and selection of Material Handling Equipment (MHE) under manufacturing environment. Ahin and Turkbey, discussed the Dynamic Facility Layout Problem; so as to determine layouts for each period in the planning horizon such that the sum of material handling and rearrangement costs are minimized.

Hybrid Genetic algorithm is used by Young Hae Lee [6] for shape based facility layout. Hybrid Ant System algorithm is used by Alan R. Mckendall for dynamic layout. Balakrishnan et al. have used Hybrid genetic algorithm for dynamic plant layout. Hybrid Tabu Simulated annealing algorithm is used by Ramzan Ahin for dynamic plant layout. A hybrid heuristic model is proposed by S. K. Deb. Hybrid GA simulation approach is developed by Azadeh.

3 Discussion on optimization techniques

When the flows of materials between departments changes during a planning horizon, the SFLP becomes dynamic, and this problem is known as the dynamic facility layout problem (DFLP). The DFLP is based on the anticipated changes in flow that can occur in the future. The prospective future is divided into a number of time periods. Moreover, the future can be divided into any number of periods, and a period may be defined in weeks, months, or years. The solution for the SFLP is a single layout, and the solution for the DFLP is a layout plan and a layout plan for the DFLP is a series of layouts, and each layout is associated with a period [4].

It is observed that large number of researchers have used Genetic Algorithm for optimization. Also, few researchers are using Simulated annealing, Ant Colony, Neural Network, Fuzzy Logic etc. Most of the researchers have considered material handling cost and distance traveled as criteria for optimization. Some researchers have considered the departmental area of unequal sizes which is more practical. Some researchers have made attempts to use hybrid algorithm for optimization of DFLP, which has resulted in improved efficiency [7]. During the last two decades, the advancement of computing facilities and availability of software tools have helped in analyzing manufacturing facility layout. The Computer Aided Design (CAD) packages help in designing and visualizing facility layout. Several algorithms have been developed to design the layout with objectives such as reduction of handling cost, low capital investment, maximum utilization of space, reduction of inventory etc.

4 Formulation

FLP has been generally formulated as a QAP introduced by Koopmans and Beckman [8] which is NP-complete [9–11] and one of the frequently used formulations to resolve FLP. The following formulation is adopted from Koopmans and Beckman [7].

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{N} f\,\pi_{it}\pi_{jt}d_{ij} + \sum_{i=1}^{N}\sum_{t=2}^{T}(r_{\pi_{it}}x_{it})$$

where

$$\sum_{j=0}^{n}(X_{ij}) = \text{ for all i, } 1\ldots n$$

$$\sum_{j=0}^{n}(X_{ij}) = \text{ for all j, } 1\ldots n$$

X_{ij} = 1 if facility "i" is located/assigned to location "j".
X_{ij} = 0 if facility "i" is not located/assigned to location "j".
F_{ik} is the flow between two facilities i and k.
D_{jl} is the distance between two locations j and l.

For the DFLP, it is assumed that the flow data for each period remains constant throughout the period. Therefore, the layout for each period in the planning horizon can be obtained by solving the SFLP for each period using the QAP formulation. If π_t is used to represent the layout for each time period t ($t = 1, 2, \ldots, T$) with N departments, then one solution representation is $\pi t = (\pi_{1t}, \pi_{2t}, \ldots, \pi_{Nt})$, where π_{it} represents the department assigned to location i ($i = 1, 2, \ldots, N$) at time period t . Hence, a solution representation for the DFLP is

$$\pi = \{ \pi_1, \pi_2 \ldots \pi_T \} = \{(\pi_{11}, \pi_{21}, .., \pi_{N1}), (\pi_{12}, \pi_{22}, .., \pi_{N2}), \ldots, (\pi_{1T}, \pi_{2T}, \ldots, \pi_{NT})\}$$

The material-handling cost for each layout π_t in each time period t can be obtained by calculating

$$\sum_{i=1}^{N}\sum_{j=1}^{N}(f\pi_{it}\pi_{jt}d_{ij}) = \qquad \text{for } t = 1,2,3 \ldots T$$

As a result, the total material-handling cost for the layout plan, π, is

$$\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{t=1}^{N} (f\pi_{it}\pi_{jt}d_{ij})$$

If the layout between consecutive periods changes (i.e., the locations of two or more departments change), then the cost of moving departments from one location to another needs to be considered. This cost is called the rearrangement cost. The rearrangement cost is,

$$\sum_{i=1}^{N} \sum_{t=2}^{T} (r_{\pi_{it}} x_{it})$$

where $r\, \pi_{it}$ is the arrangement cost for moving department π_{it} to location i in period t.

Position figures (see Fig.1) and tables at the tops and bottoms of columns. Please avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table names and table captions should be above the tables. Number the figures and tables consecutively and use the figure number and table number when referring to a figure (Fig. 1) or figures (Figs. 2, 3) and a table (see Table 1; see Tables 2, 3, etc.)

5 Problem

Here a virtual problem is considered. The tables for cost, flow and relationship are developed. Cost matrix – I, indicates the cost matrix in the time period – I. Here the dynamics of the problem is considered for two periods only. The shifting cost per department is considered as Rs. 50/department. It is explained as follows.

Suppose for the period – I, the final layout is,

E	A	B	F	G	C	J	D	H	I

and for the period – II, the final layout is,

E	A	B	F	C	G	H	D	J	I

It is observed that in the second final layout C, G and J, H departments are changed. So the total department shifting cost is Rs. 50 X 4 = Rs. 200.
So, the total cost = total layout cost + total department shifting cost.

Table 1 Cost Matrix -I

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	58	78	38	56	87	36	57	57	66
B		0	45	55	54	25	67	65	67	58
C			0	46	57	35	35	85	85	88
D				0	47	75	45	75	75	59
E					0	65	35	66	64	46
F						0	35	65	57	68
G							0	66	66	40
H								0	45	50
I									0	55
J										0

Table 2 Flow Matrix -I

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	12	23	11	17	18	9	8	12	11
B		0	13	16	17	18	11	14	20	16
C			0	22	15	18	19	12	10	18
D				0	15	22	19	14	11	19
E					0	14	15	21	21	8
F						0	14	16	17	14
G							0	18	19	15
H								0	13	11
I									0	12
J										0

Table 3 Relationship Matrix-1

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	A	E	E	I	I	O	U	I	E
B		0	X	I	O	I	A	E	I	E
C			0	U	A	I	A	X	E	A
D				0	U	A	X	E	E	E
E					0	E	U	I	I	U
F						0	U	I	E	I
G							0	I	E	A
H								0	I	I
I									0	A
J										0

Table 4 Cost Matrix - II

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	60	78	39	36	55	46	57	57	66
B		0	44	55	54	35	67	85	67	68
C			0	56	57	55	35	85	85	88
D				0	47	75	45	85	75	59
E					0	65	55	66	64	46
F						0	35	95	57	68
G							0	76	76	50
H								0	55	60
I									0	55
J										0

Table 5 Flow Matrix-II

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	9	22	14	15	18	19	8	12	11
B		0	13	16	17	18	10	14	20	16
C			0	22	11	18	19	12	11	18
D				0	15	22	15	14	11	19
E					0	24	15	21	21	8
F						0	15	16	18	14
G							0	18	19	15
H								0	23	31
I									0	12
J										0

Table 6 Relationship Matrix-II

	A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***
A	0	E	E	E	E	E	E	U	X	E
B		0	E	I	O	I	A	E	I	E
C			0	X	U	I	E	X	E	A
D				0	U	A	X	E	E	E
E					0	E	E	I	E	U
F						0	U	I	E	I
G							0	I	E	A
H								0	U	I
I									0	A
J										0

6 Results

First of all, the results are obtained for only Cost – I and Flow – I, and are displayed in table 7. Then the same problem is considered along with relationship matrix – I. Its results are displayed in table 8. Then the same problem is considered in dynamic conditions along with Cost – II, Flow – II, and relationship – II. With department shifting cost Rs. 50/department. To solve the above QAP, the GA techniques are used in MATLAB.

Table 7 Results for the problem in table 1 & 2

Generation No.	Total final cost	Final Chromosome or Layout	Time taken
11	4727.00	4 1 8 9 3 2 6 7 5 10	Time elapsed : 2.6563 seconds
2	4927.00	8 9 10 5 7 1 4 3 2 6	Time elapsed : 2.4844 seconds
12	5088.00	4 9 8 10 5 7 1 2 3 6	Time elapsed : 2.4844 seconds
3	4730.00	3 6 2 4 1 7 5 10 8 9	Time elapsed : 2.5938 seconds
6	5405.00	1 4 5 10 8 9 7 6 2 3	Time elapsed : 2.6719 seconds
7	4935.00	6 2 3 8 9 10 5 7 1 4	Time elapsed : 2.8125 seconds
7	5018.00	3 9 4 5 10 8 1 7 6 2	Time elapsed : 2.9688 seconds
22	5095.00	6 2 4 1 7 3 5 10 8 9	Time elapsed : 4.1094 seconds
18	4712.00	6 2 3 7 5 10 9 8 1 4	Time elapsed : 4.2813 seconds
24	4865.00	9 8 10 5 7 1 4 2 3 6	Time elapsed : 4.5313 seconds
23	5082.00	3 7 5 10 8 9 4 1 2 6	Time elapsed : 4.6250 seconds
15	5023.00	10 5 4 2 3 6 7 1 8 9	Time elapsed : 4.4844 seconds
5	5222.00	2 3 6 9 8 1 7 10 5 4	Time elapsed : 4.4688 seconds
1	5192.00	3 9 8 10 5 6 2 7 1 4	Time elapsed : 4.4844 seconds
18	5167.00	4 1 10 5 7 6 2 3 8 9	Time elapsed : 4.5938 seconds
25	4923.00	4 5 10 7 1 8 9 3 2 6	Time elapsed : 4.0469 seconds

Table 8 Results for the problem in table 1, 2 & 3

Generation No.	Total final cost	Final Chromosome or Layout	Time taken
19	6990.0000	1 4 8 2 7 10 9 3 5 6	Time elapsed : 4.5625 seconds
21	7433.0000	10 1 2 7 3 5 6 9 4 8	Time elapsed : 4.5938 seconds
15	7770.0000	5 3 7 10 9 1 2 8 4 6	Time elapsed : 4.1719 seconds
15	6776.0000	8 4 1 2 7 10 9 3 5 6	Time elapsed : 4.2500 seconds
12	6195.0000	8 10 1 4 9 6 2 7 3 5	Time elapsed : 4.3594 seconds
19	6253.0000	5 3 7 10 8 4 1 2 6 9	Time elapsed : 4.5156 seconds
19	7837.0000	8 2 1 10 7 3 5 6 4 9	Time elapsed : 4.9219 seconds
12	7408.0000	8 9 10 2 7 3 5 6 4 1	Time elapsed : 5.4844 seconds
9	7423.0000	5 3 7 10 9 6 4 1 2 8	Time elapsed : 4.8438 seconds
8	7381.0000	9 6 5 3 7 10 1 2 8 4	Time elapsed : 4.0469 seconds
15	6029.0000	7 3 5 6 2 1 4 9 10 8	Time elapsed : 4.1094 seconds
9	7698.0000	4 6 5 3 7 2 8 9 10 1	Time elapsed : 4.3750 seconds
24	7156.0000	4 9 6 5 3 7 10 1 2 8	Time elapsed : 4.5156 seconds
1	8008.0000	1 2 7 10 9 3 5 6 4 8	Time elapsed : 4.0469 seconds
24	6591.0000	6 5 3 9 8 2 7 10 1 4	Time elapsed : 4.5156 seconds
3	6943.0000	8 4 1 2 7 3 5 6 10 9	Time elapsed : 4.8125 seconds
17	6839.0000	1 4 9 6 5 3 7 2 8 10	Time elapsed : 4.0000 seconds
24	7661.0000	1 2 8 10 7 3 5 6 4 9	Time elapsed : 4.3750 seconds
17	7039.0000	6 4 1 2 8 9 10 7 3 5	Time elapsed : 4.4844 seconds
7	6439.0000	6 5 3 7 10 9 8 4 1 2	Time elapsed : 5.0313 seconds

Table 9 Results for the problem in table 1, 2, 3 & 4, 5, 6 (Dynamic)

First layout		Second layout	Total layout cost	Shifting cost	Total cost	Time elapsed
4 5 7 1 2 6 3 8 9 10	+	3 7 9 10 5 4 1 8 2 6	12259	450	12709	4.5000
2 7 1 4 5 10 9 3 6 8	+	10 1 5 4 7 3 2 6 9 8	12536	400	12936	3.6875
8 3 7 5 10 9 4 1 2 6	+	8 4 5 1 2 3 9 10 7 6	12044	400	12444	4.2031
4 8 9 1 7 2 6 3 5 10	+	3 5 10 7 6 9 4 1 8 2	11996	500	12496	4.3906
6 2 3 9 8 1 7 10 5 4	+	8 3 6 9 10 5 1 2 7 4	11412	400	11812	3.9844
1 4 5 10 9 8 7 3 6 2	+	8 1 4 9 3 2 5 10 6 7	11766	450	12216	3.9063
4 1 7 6 3 9 8 2 5 10	+	2 6 8 1 4 9 10 5 7 3	11988	450	12438	3.9688
5 7 2 6 3 9 8 10 1 4	+	5 7 6 2 3 9 10 1 4 8	12080	300	12380	4.1406
4 2 6 3 7 5 10 9 1 8	+	8 1 4 9 6 2 7 10 5 3	11216	500	11716	4.2188
3 2 4 9 8 6 7 1 10 5	+	5 3 2 6 8 1 4 9 10 7	12409	400	12809	3.8906
6 2 1 9 3 7 5 10 8 4	+	10 6 7 5 3 2 9 1 8 4	13009	350	13359	3.9688
1 7 5 4 2 6 3 9 8 10	+	8 1 5 2 4 9 10 6 7 3	11920	450	12370	4.2188
6 3 7 1 9 4 5 10 8 2	+	6 2 4 9 10 1 8 3 5 7	12310	450	12760	4.0156
9 8 10 5 4 2 6 3 7 1	+	8 5 10 9 3 2 6 7 4 1	11454	300	11754	4.0625
8 10 5 3 2 6 7 1 4 9	+	10 9 5 4 8 1 2 6 7 3	11580	450	12030	4.2500
4 3 2 1 7 5 10 8 9 6	+	8 6 2 1 4 5 3 7 10 9	12257	350	12607	4.2344
6 2 4 1 7 5 3 9 10 8	+	6 2 1 8 3 4 9 10 7 5	12450	400	12850	4.2656
3 6 7 5 10 8 2 9 1 4	+	8 9 4 1 7 6 2 3 5 10	12147	450	12597	4.5156
9 10 8 4 1 7 3 5 6 2	+	9 10 4 1 8 5 3 7 2 6	12643	350	12993	4.3906
2 6 7 3 9 1 10 5 4 8	+	8 4 1 2 6 7 3 5 10 9	11739	450	12189	4.1875

7 Conclusion

In this paper a virtual problem is solved in both static and dynamic conditions. The results are displayed and it is observed that as none of the objectives are increasing i.e. the problem becomes multi objective, the optimum layout changes. Since we are using Genetic Algorithm, it is observed that the results for above problem are varying, as GA gives near to the global optima answers but not the exact ones.

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