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Full Length Research Paper

Cost optimization by genetic algorithm technique for Y-Oscillatory plant layout

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Facility layout design generally refers to the location of different types of facilities and determination of the configuration of certain type of facilities. The purpose of the present work to minimize the cost incurred amongst the departments of a certain layout by considering the vertical flow pattern. There are varieties of choices available to implement the optimal layout so that the cost may be minimized. But in the present work, genetic algorithm has been utilized to get the optimal result at minimum time. ALDEP, CORELAP and CRAFT are quite popular computerized techniques for finding out the optimal layout design, but it has been found out that the genetic algorithm has wide number of alternatives through which different types of layout can be designed at minimum time without any hazards. Since there are many types of standard layout available to determine the cost, but Y-Oscillatory type layout has been considered in the present work as a case study to show the probable changes of transportation cost. The method, which has been given in the present work, has a wide range of application. This idea can be applied in any type of layout in manufacturing organization or any corporate sector or any pharmaceutical company and so on. This work has been performed on the basis of facility layout design. Since this type of work already been implemented through the standard methodologies like, ALDEP, CORELAP or CRAFT techniques, so the author tries to apply it on the manufacturing plant with the help of genetic algorithm tool and found satisfactory result.

Key words: Facility layout, genetic algorithm, mutation, crossover, fitness function.

INTRODUCTION

In any industrial sector, the manufacturing engineers generally decide the sequence of operations so as to transform the raw materials into the finished products. Based on the selection and knowledge on the interaction between various departments, the facility layout designers can plan to minimize the total material handling cost. But the problems have been arisen to decide the proper position of various departments on a particular layout (Lacksonen, 1997). Layout design problems can be easily solved with the help of some broad features like, quantitative and qualitative approaches. Usually, the layout has two main categories:

i. Single layout.
ii. Multiple layout.

Some of the basic criterion can be considered with respect to facility layout designing system:

i. Inventory system.
ii. Production planning.
iii. Scheduling.

Hence, to improve the manufacturing system, layout design can play an important role for cost reduction as well as the production system improvement (Meller, 1997). In any layout designing problem, generally the distances amongst various departments and the material flow pattern must be considered. Figure 1 shows the

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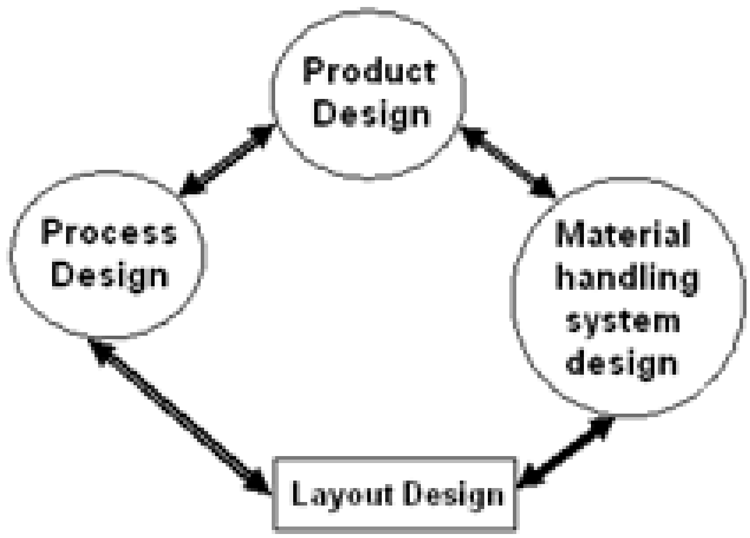

Figure 1. Interaction between different designs.

interaction amongst the design processes.

There are some drawbacks involved while designing any layout under a manufacturing environment:

If the type of products change continuously during manufacturing
If the type of products may change in future
} Due to these phenomenon facility layout changes after a certain period

FACILITY LAYOUT DESIGN

Generally, in the layout designing problems, some of the important features must be considered in the following stages such as:

Stages

1. Formation of the problem: At the first stage, problems formulation is very much important factor as it is having black box concept where the best location of the facilities can be searched out properly.
2. Analysis of the problem: At the second stage, identification of the criteria in evaluating the problems is very much essential and accordingly, the corrective action should be taken.
3. Searching the alternative solution: At the third stage, while searching the alternatives, some of the vital features must be followed such as:

i. Exerting the necessary efforts.
ii. Questioning attitude must be developed.
iii. Establish many alternatives to achieve the goal.
iv. Avoid the small rejections.
v. Consulting with articles, books or other resources.
vi. Brainstorming processes among the group of people are necessary.

4. Selection of the solution: At the fourth stage, since alternative solutions are available, so amongst themselves, the best solution must be taken into consideration. There are some key factors to be followed while considering the alternative solutions like:

i. Flexibility of layout.
ii. Material handling effectiveness.
iii. Space utilization.
iv. Working conditions.
v. Proper supervision and control.
vi. Equipment utilization.
vii. Savings, returns and profitability.

If m = number of factors involved in layout designing and n = number of alternatives, then, $(mn / 2)(n - 1)$ = required number of comparisons
5. Specification of the solution: At the last stage, the detailed specifications are required for implementing the layout and accordingly the facilities can be placed properly.

The assignment of various departments in every location in a particular layout has found out an important task for any manufacturing industry. Generally, the size of the departments and interaction amongst them are not fixed. Hence, the optimal layout is essential for floating characterized layout. Let, m = number of facilities and n = number of locations. Theses two factors have to be assigned in such a way that $m \leq n$ should be satisfied. By considering this view in the present work, the minimization of cost involved in interacting different departments

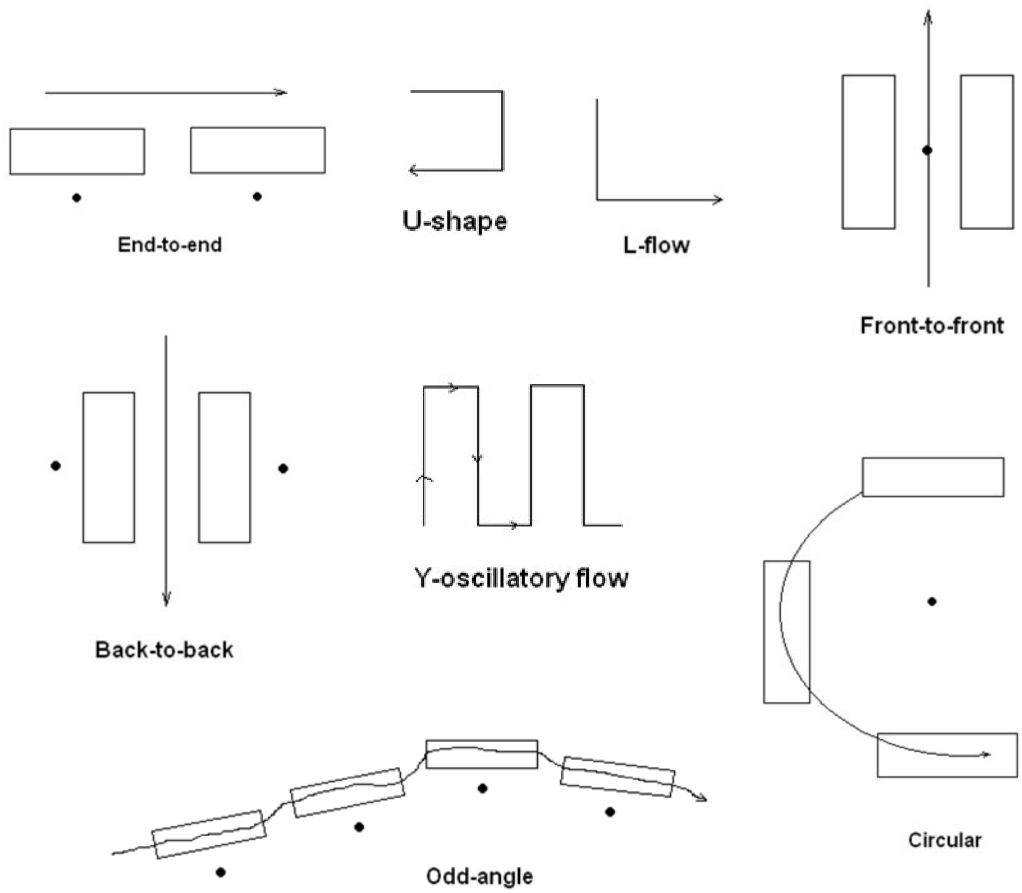

Figure 2. Different types of flow patterns.

has been concentrated. Hence, the objective function has been considered as:

$$C = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \left[f_{ij} \, (c_{ij} . d_{ij}) \right] \quad \text{................ (i)}$$

where, C = total variable cost, i and j = number of departments, n = total number of departments, f_{ij} = work flow from i to j, c_{ij} = unit cost of work flow from i to j, d_{ij} = distance between i and j. Various types of flow patterns have been illustrated in Figure 2.

Mathematical interpretation in layout design

Facility layout designing problems can be solved by quantitatively and qualitatively, but it requires the optimality both in single as well as multiple layout problems. Some of the mathematical formulations involved in layout design such as:

i. Rectilinear distance location problem

Here, the total transportation cost associated with the allocated facilities can be interpreted as:

$$f(x_1, x_2, x_3, \ldots\ldots, x_n) = \sum_{1 \leq j \leq k \leq n} v_{jk} . d(x_j, x_k) + \sum_{j=1}^{n} \sum_{i=1}^{m} w_{ji} . d(x_j, p_i)$$

Where, v_{jk} = annual transportation cost / unit distance between new facilities j and k. w_{ji} = annual transportation cost / unit distance between new facility j and existing facility i. d (x_j, x_k) = distance between the location of new facilities j and k. d (x_j, p_i) = distance between new facility j and existing facility i.

ii. Euclidean distance location problem

In case of multi layout problems, minimization function can be expressed as:

$$\text{minimize } f(x_1, x_2, x_3, \ldots\ldots, x_n) = \sum_{1 \leq j \leq k \leq n} v_{jk} . \sqrt{(x_j - x_k)^2 + (y_j - y_k)^2} + \sum_{j=1}^{n} \sum_{i=1}^{m} w_{ji} . \sqrt{(x_j - a_i)^2 + (y_j - b_i)^2}$$

where, x_1, x_2, x_3, ……….., x_n = points of location, n = number of new facilities

v_{jk} = annual transportation cost / unit distance between new facilities j and k.

w_{ji} = annual transportation cost / unit distance between new facility j and existing facility i.

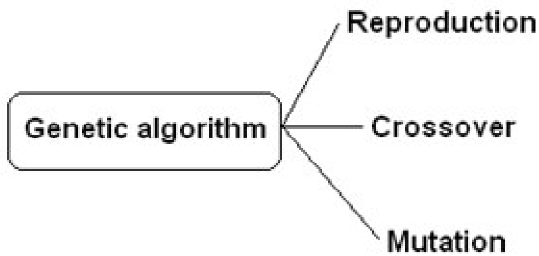

Figure 3. Different operations in GA.

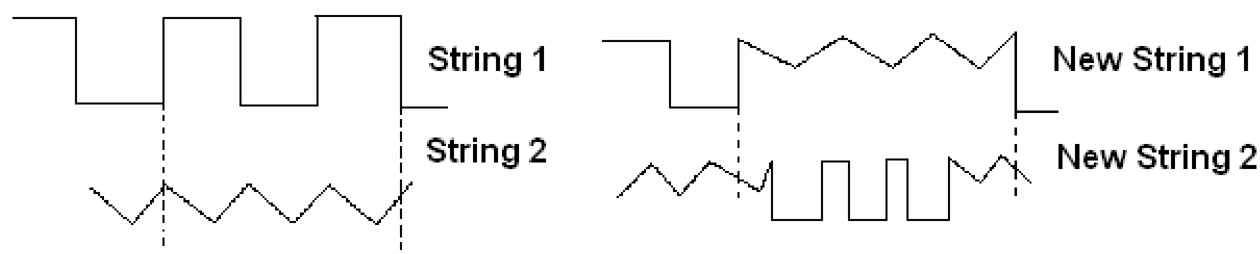

Figure 4. Crossover operation for generation of new strings.

iii. Squared Euclidean distance location problem

In case of multiple facility layout problems, the squared distance can be written as:

$$f[(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots, (x_n, y_n)] = \sum_{1 \leq j \leq k \leq n} v_{jk} \sqrt{(x_j - x_k)^2 + (y_j - y_k)^2} + \sum_{j=1}^{n} \sum_{i=1}^{m} w_{ji} \cdot \sqrt{(x_j - a_i)^2 + (y_j - b_i)^2}$$

Where, (x_1, y_1), (x_2, y_2), (x_3, y_3), …………., (x_n, y_n) = points of locations for new facilities.
(a_1, b_1), (a_2, b_2), (a_3, b_3), ……………., (a_n, b_n) = points of locations for the existing facilities.

iv. Computerized layout design

Though layout designing problems can be solved by various methodologies, but there are some computer algorithms available through which the alternative solution can be prepared properly:

ALDEP – It is known as "automated layout design program".
CORELAP – It is known as "computerized relationship layout planning".
CRAFT – It is known as "computerized relative allocation of facilities technique".

GENETIC ALGORITHM IN LAYOUT PROBLEMS

Genetic algorithm (GA) has been found as one of the simple searching technique in optimization problems. GA can give the set of feasible solutions and generates the new solutions randomly through survival mode (Islier 1998; Yaman and Balibek 1999). The concept of chromosome represented in genetic coding, which can follow the sequence of integer numbers and can be compared with the number of facilities. Apart from that fitness value of each individual should be computed for making proper solution. The operators of GA have been shown in Figure 3.

Reproduction process can give the selection of individuals from a known population based on their fitness function. The higher value of fitness function will have the priority for crossover and mutation operations. The count of each string can be represented as:

$$e_i = (F_i / F').N$$

Where, N = population size, F_i = fitness value of i^{th} string, F' = average fitness value of all strings.

If e_i = 6.78, then the number of samples to be allocated is 6 and 0.78 which is the probability of acceptance for next generation. Crossover operation can be used to produce the new offspring from the selected pair of solutions in the current population. The methodology of doing crossing different strings has been given in Figure 4.

Whereas, mutation operation is utilized for altering the values of the string positions. Generally, mutation can be used after crossover operation. Figure 5 shows the typical operation of mutation.

Fitness function for optimizing the problems

In genetic algorithm techniques, the fitness function can be computed for each string in the given population and the maximum value of fitness can be treated as the most

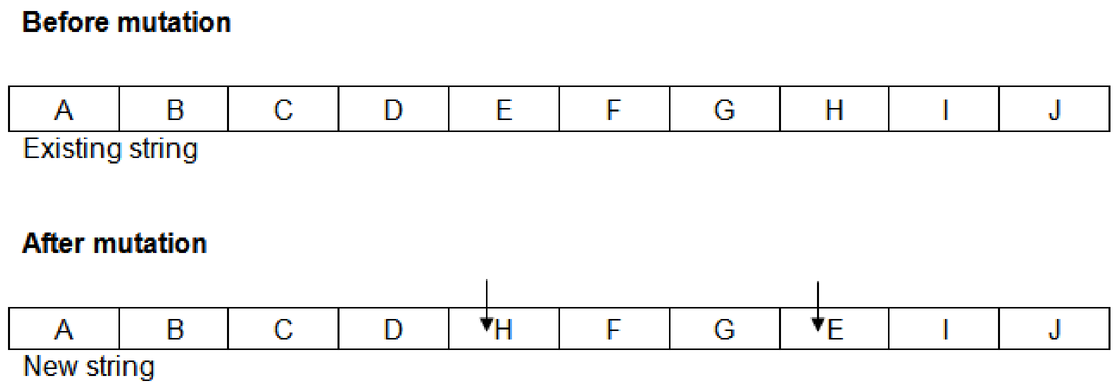

Figure 5. Mutation operation.

suitable solution (Rao et al., 1999; Chittratanawat et al., 1999). But in the present work, mainly minimization of transportation cost has been considered as one of the better fitness for layout design. Mathematically, it can be represented as:

$$F = [(TP - \mu_{TP}) / \sigma_{TP}] - [(TT - \mu_{TT}) / \sigma_{TT}]$$

Where, F = fitness function, TP = actual throughput rate, TT = actual traveling time / trip,
μ_{TP} = mean of throughput rate, μ_{TT} = mean of traveling time / trip, σ_{TP} = standard deviation of throughput rate and σ_{TT} = standard deviation of traveling time / trip.

Based on the fitness function, the layout design has been developed successfully. (Ghosh 2001; Kochhar et al., 1999; Eaglesham, 1998; Goldberg, 1999)

OPTIMALITY IN LAYOUT DESIGN

The following steps have been considered in defining the optimal layout in the present work:

Step-1: Initially the population has been considered as 50.
Step-2: Maximum chromosome string length has been considered as 10. Therefore, the system considered as 10 departments.
Step-3: Crossover and mutation operations have been performed successfully for the given problem.
Step-4: Combination of crossover and mutation operations has been formulated in such a way that the location site can be identified properly, 25-42-5-9 combination can be represented as, 25-42 is the string number and 5-9 is the location site.
Step-5: Probability of crossover has been considered as, 46 / 50 = 0.92, where maximum number of string combination = 46.
Step-6: Probability of mutation has been considered as, 4 /50 = 0.08, where maximum number of string combination = 4.
Step-7: All departments considered as equal size and rectangular in shape.
Step-8: Area of each department considered as 16 square units and total area as, 160 square units.
Step-9: Distance between the departments has been considered as Euclidean nature and Y-Oscillatory path.
Step-10: Transportation cost for traveling from one department to another has been calculated at each iteration and the process continued till the minimum transportation cost achieved.
Step-11: Sizes of the materials transported have been considered as equal in nature.

CASE STUDY

In the present work, basically a manufacturing industry has been considered as a case study, where the population size has been taken as 50 and the length of chromosome or string as 10. According to the given outcomes, the relationships between the number of generations and the fitness functional values could be established. In this way, from the parent generation to the successive generations, the least transportation costs have been considered individually. Table 1 shows the possible transportation costs against the number of generations.

It has been observed that after 14th generation the stability in the fitness function values have been occurred and the mean values of the fitness function has also been going down.

After successful operations for layout designing processing, before crossover and after crossover techniques along with the mutation methods application have been shown in Figures 6 and 7, respectively. Based on the values as discussed in Table 1, the relationships among the minimum, mean and standard deviation fitness

Table 1. Fitness function for successive operations

S/No.	Length of string	Fitness function values		
		Minimum	Mean	Standard deviation
1.	3-4-5-6-7-8-9-10-1-2	4612.07	4889.92	147.75
2.	3-4-5-6-7-2-9-8-1-10	4558.04	4816.3	165.3
3.	3-4-7-6-5-10-8-9-1-2	4549.32	4692.36	94.54
4.	1-2-5-3-7-4-6-9-10-8	4435.03	4647.75	99.93
5.	1-2-5-3-7-4-9-6-10-8	4426.16	4635.96	117.37
6.	1-2-5-3-7-4-9-6-10-8	4426.16	4589.17	116.39
7.	1-2-5-3-8-7-9-6-10-4	4420.04	4563.66	113.07
8.	1-2-5-7-6-3-9-8-10-4	4402.17	4537.82	102.23
9.	1-2-5-7-8-3-6-9-10-4	4382.58	4535.41	152.91
10.	1-2-7-5-8-3-6-9-10-4	4377.75	4408	41.93
11.	1-2-5-3-6-7-9-8-10-4	4373.47	4400.94	18.36
12.	1-2-5-3-6-7-8-9-10-4	4368.52	4405.57	89.95
13.	2-1-7-5-8-3-6-9-10-4	4360.72	4386.57	37.54
14.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
15.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
16.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
17.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
18.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
19.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36
20.	2-1-3-5-8-7-6-9-10-4	4359.13	4370.6	11.36

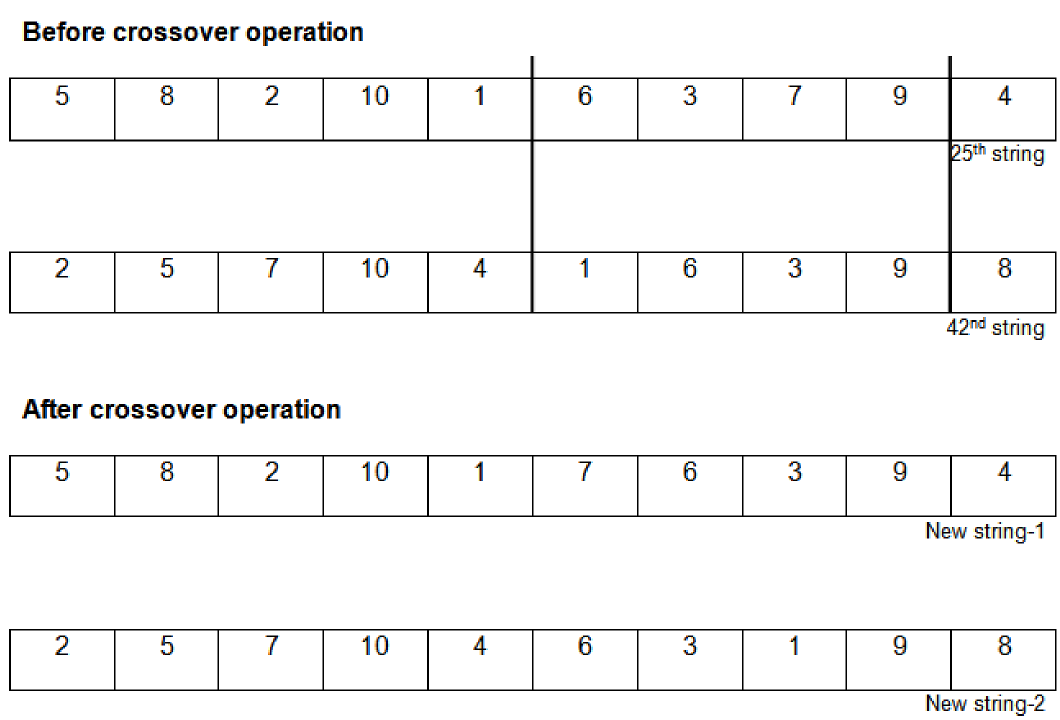

Figure 6. Crossover operation.

functions have been explained in Figures 8, 9 and 10.

The Y-Oscillatory path has been generated by the present experimentation, as shown in Figure 11. Figure12 shows the optimal layout where 10 numbers of

Before mutation

5	8	2	10	1	6	3	7	9	4

25th string

2	5	7	10	4	1	6	3	9	8

42nd string

After mutation

5	8	2	10	9	6	3	7	1	4

New string-1

2	5	7	10	9	1	6	3	4	8

New string-2

Figure 7. Mutation operation.

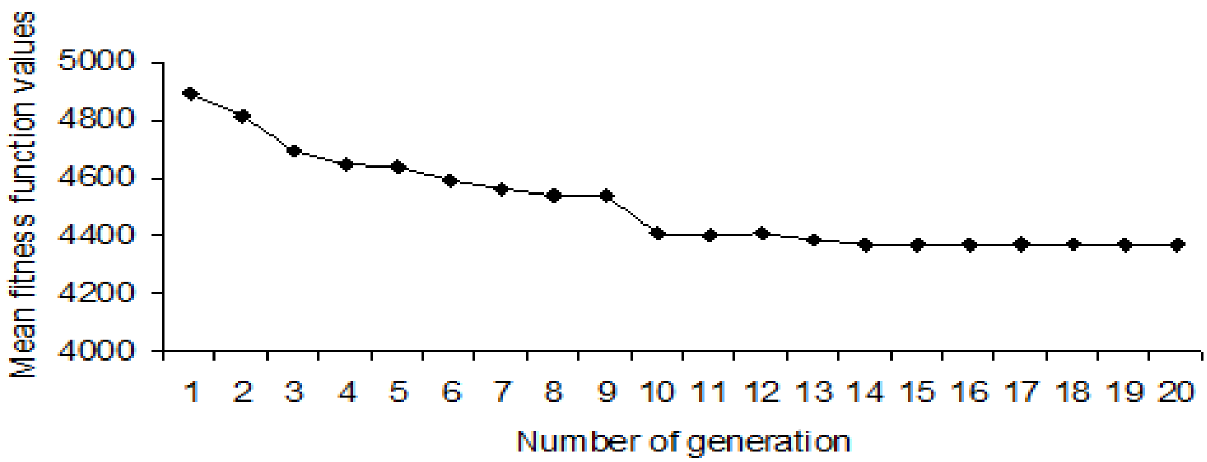

Figure 8. Trends of mean fitness function values with the number of generations.

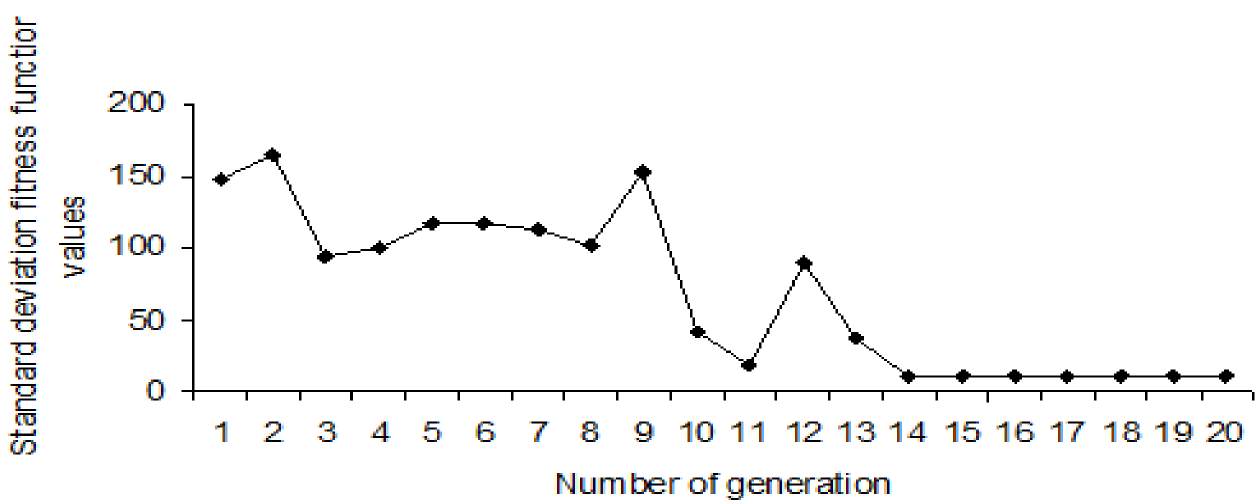

Figure 9. Relationship between number of generation with standard deviation of the fitness function.

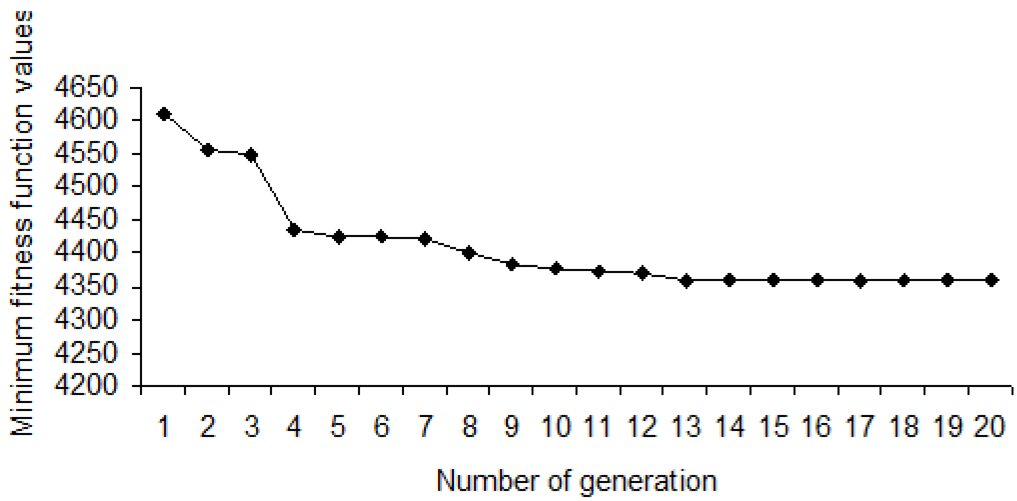

Figure 10. Relationship between number of generations and minimum fitness function values.

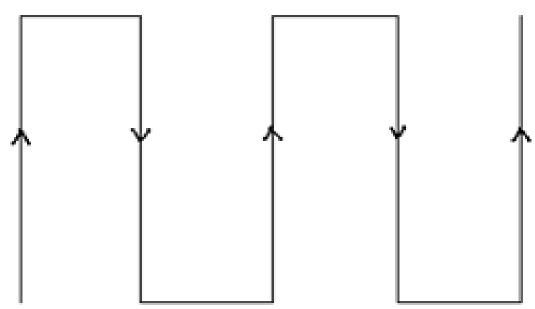

Figure 11. Y-Oscillatory path

1	3	7	6	4
2	5	8	9	10

Figure 12. Optimal layout with 10 numbers of departments.

equal sized departments have been considered based on the Y-oscillatory path. (Ponnanbalam et al., 2000; Jaydeep et al., 2003; Charles, 2004; Terushige, 2004; Shayan et al., 2004)

CONCLUSION

Optimal layout with various departments in a plant has found a unique trouble in the arena of optimization for any industry. In these kinds of problems, generally minimization of total material handling cost is essential to work out. In the present work, mainly genetic algorithm has been utilized in a medium sized plant where 10 numbers of departments with sufficient facilities have been considered. The following data has been considered for genetic operation of the problem:

Size of the population = 50.
String length = 10.
Probability of crossover = 0.92.
Probability of mutation = 0.08.

Based on these, the minimum fitness function value has been observed at 14th generation after that it was found in steady condition. Optimal combination in the layout has found as 2-1-3-5-8-7-6-9-10-4 with minimum transportation cost as Rs.4359.13. In this way, the work can also be solved by using simulated annealing, tabu search techniques, fuzzy expert systems etc. in the field of cost engineering.

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