# Optimal Facility Layout Problem Solution Using Genetic Algorithm 

Maricar G. Misola and Bryan B. Navarro


#### Abstract

Facility Layout Problem (FLP) is one of the essential problems of several types of manufacturing and service sector. It is an optimization problem on which the main objective is to obtain the efficient locations, arrangement and order of the facilities. In the literature, there are numerous facility layout problem research presented and have used meta-heuristic approaches to achieve optimal facility layout design. This paper presented genetic algorithm to solve facility layout problem; to minimize total cost function. The performance of the proposed approach was verified and compared using problems in the literature.


Keywords-Facility Layout Problem, Genetic Algorithm, Material Handling Cost, Meta-heuristic Approach.

## I. Introduction

FACILITY layout is an arrangement of everything needed for production of goods or delivery of services. A facility is an entity that facilitates the performance of any job. It may be a machine tool, a work center, a manufacturing cell, a machine shop, a department, a warehouse, etc. Layout problems are usually found in manufacturing systems which is related to the location of facilities in a plant. A good placement of facilities can contribute to the overall efficiency of operations, reduce manufacturing cost, decrease lead times, and increase productivity. Tompkins and White [1] discuss about $50 \%$ of total operating expenses can be reduced through a good placement of facilities. Aleisha and Lin [2] pointed out that simulation approaches are frequently applied to gauge the performance of the layout. Drira, Pierreval, and Hajri-Gabouj [3] presented a survey of resolution approaches in solving facility layout problems.

Genetic algorithm (GA) has been widely used in optimization with binary and continuous variable [4] and quite popular in solving facility layout problem.

Chan and Tansri [5] studied different genetic crossover operators to solve facility layout problem. They compared the partially mapped crossover (PMX), the order crossover (OX), and the cycle crossover (CX). The result shows that PMX

This work was supported by the Research and Development Office of the Technological Institute of the Philippines and Commission on Higher Education (CHED).
M. G. Misola is with the Industrial Engineering Department, College of Engineering and Architecture, Technological Institute of the Philippines, Manila, Philippines and currently taking up Master of Engineering, major in Industrial Engineering at Mapua Institute of Technology, Manila, Philippines (e-mail: maricar_misola@yahoo.com).
B. B. Navarro is with the Electrical Engineering Department, College of Engineering and Architecture, Technological Institute of the Philippines, Quezon City, Philippines (e-mail:bryanbnavarro@yahoo.com).
operator provided excellent results. Mihajlovic, Zivkovic, Strbac, Zivkovic, and Jovanovic [6] proposed genetic algorithm to minimize material handling costs in manufacturing layout problem. Adel El-Baz [7] proposed genetic algorithm to solve the problem of optimal facilities layout in manufacturing systems design. He considers various material flow patterns of manufacturing environments. Mak, Wong, and Chan [8] developed a genetic algorithm to solve facility layout problems. Liu and Li [9] presented a genetic algorithms-based approach to solve supply chain-oriented and dynamic discrete facility layout problem. Liu, Bo, Ma, and Meng [10] presents a creative approach to solve dynamic planning and scheduling problems in hybrid distributed manufacturing execution system using single and parallel genetic algorithms. Kulkarni and Shanker [11] adopted a genetic algorithm methodology to solve quadratic assignment problems in order to minimize material handling cost. Zhang, Zhang, Xia, Lu, and Jiang [12] proposed an improved genetic algorithm to solve unidirectional loop layout to optimize the facility layout in workshop. They used multipoint crossover operator of parent and child competition. Ripon, Glette, Hovin, and Torresen [13] presented a genetic algorithm to solve the integrated job shop scheduling problem and facility layout problem considering multi-objective and paretooptimality. Aiello, La Scalia, and Enea [14] developed a multi objective genetic algorithm to solve facility layout problem based on slicing structure encoding. They used four objective functions of the block layout problem but they did not incorporate it into single objective function.
In this paper, we used genetic algorithm to solve facility layout problem and hence minimizing the total material handling cost. The objective function is the total material handling cost. The difference of the proposed method to other works is the conversion of the objective values to its relative fitness before the selection operator. Most of the methods in the literature have codification difficulties. To make the coding of the GA simpler, swap mutation [6] and swapped crossover [11] was adopted.

## II. Problem Formulation

In manufacturing systems, solving facility layout problem can minimize material handling cost of the system. To determine the material handling cost for a possible layout of the system, certain parameters have been known such as the amount of material flow or production volumes among equipment, the handling cost of per unit material in per unit distance between equipment, and the rectilinear distance between equipment.

For the optimization problem, the objective function TC is the total material handling cost of the system. The total material handling cost of the system is a measure of how the facilities are arranged in a minimized manner. The optimization problem is formulated as:

$$
\begin{equation*}
\min T C=\sum_{i=1}^{n} \sum_{j=1}^{n} F_{i j} C_{i j} D_{i j} \tag{1}
\end{equation*}
$$

where $F_{i j}$ is the amount of material flow among equipment $i$ and $j, C_{i j}$ is the unit material handling cost between locations of equipment $i$ and $j$, and $D_{i j}$ is the rectilinear distance between the centroids of locations between equipment $i$ and $j$ and $T C$ is the total material handling cost of the system.

## III. Facility Layout Problem Using Genetic Algorithm

The starting operator of the GA is the generation of initial population, which was randomly generated. The representation of an individual is a single-level string. The length of chromosome string is equal to the number of position of the facilities. Fig. 1 shows how the initial parent is encoded.

| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |  |  | 12 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Facility | 4 | 2 | 12 | 9 | 5 | 11 | 10 | 3 | 8 | 1 | 6 | 7 |
| Parent | 4 | 2 | 12 | 9 | 5 | 11 | 10 | 3 | 8 | 1 | 6 | 7 |

Fig. 1 Encoding of Chromosomes
After the generation of initial population, it will call the objective function, which is the total material handling cost, and passes the generated population as an input. For each individual, the objective function is then calculated.

The fitness function in this paper is given by [15]:

$$
\begin{gather*}
\operatorname{Fitness}\left(x_{i}\right)=\frac{(\operatorname{Nind})\left(X^{\left(x_{i}-1\right)}\right)}{\sum_{i=1}^{\text {Nind }}\left(X^{\left(x_{i}-1\right)}\right)}  \tag{2}\\
0=(M A X-1) X^{\text {Nind }-1}+\sum_{n=2}^{\text {Nind }}(M A X) X^{\text {Nind-n }} \tag{3}
\end{gather*}
$$

where $X$ is the computed real numbered root of the polynomial in (3), MAX is the selective pressure or bias towards the fittest individual, and Nind is the number of individuals.

The selection used in this paper is the roulette wheel selection. This selection methodology is used to probabilistically select individuals based on total material handling cost.

The usual single point crossover was employed. The crossover used in this paper is swapped crossover based on [11]. This method works as a single parent instead of taking two parents as in other crossover methods to generate only feasible solution. It only changes the string of the original
chromosome of one parent and swapped the remaining chromosome string in the crossover point. $P$ and $O$ denote parent and offspring respectively. Fig. 2 shows how the swapped crossover was employed:


Fig. 2 Swapped Crossover
The mutation technique employed is swap mutation [6]. It simply selects two random chromosome strings and swapped their contents. Fig. 3 shows an example of swap mutation:

## Before Mutation

| Offspring | 5 | 11 | 10 | 3 | 8 | 1 | 6 | 7 | 4 | 2 | 12 | 9 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

After Mutation

| Offspring | 5 | 11 | 10 | 7 | 8 | 1 | 6 | 3 | 4 | 2 | 12 | 9 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |

Fig. 3 Swap Mutation
After the offspring are mutated, the objective value will be calculated. Fitness-based reinsertion combined with elitism was used in this paper. The termination depends on the maximum number of generations.

## IV. Test Results and Discussions

The effectiveness of the proposed method is illustrated using two numerical examples described in the literature. The entire simulation was coded in MATLAB platform.

## A. Numerical Example 1

A comparative evaluation of the proposed method is made using benchmark numerical example. This example is taken from [5] and compared with the works of [6]-[8] that used the same example to evaluate their work. The amount of material flow and the unit material handling cost between equipment are shown in Tables I and II respectively. The plant configuration layout is a $3 x 3$ grid. The rectilinear distance between locations of equipment for the $3 x 3$ grid is tabulated for simplicity and is shown in Table III.

TABLE I
Material Flow between Equipment

| MATERIAL FLOW BETWEEN EQUIPMENT |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| From/To | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ |
| $\mathbf{1}$ | 0 | 100 | 3 | 0 | 6 | 35 | 190 | 14 | 12 |
| $\mathbf{2}$ | 0 | 0 | 6 | 8 | 109 | 78 | 1 | 1 | 104 |
| $\mathbf{3}$ | 0 | 0 | 0 | 0 | 0 | 17 | 100 | 1 | 31 |
| $\mathbf{4}$ | 0 | 0 | 0 | 0 | 100 | 1 | 247 | 178 | 1 |
| $\mathbf{5}$ | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 1 | 79 |
| $\mathbf{6}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| $\mathbf{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\mathbf{8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| $\mathbf{9}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE II

| UnIT MATERIAL HANDLING COST |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| From/To | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ |
| $\mathbf{1}$ | 0 | 1 | 2 | 3 | 3 | 4 | 2 | 6 | 7 |
| $\mathbf{2}$ | 0 | 0 | 12 | 4 | 7 | 5 | 8 | 6 | 5 |
| $\mathbf{3}$ | 0 | 0 | 0 | 5 | 9 | 1 | 1 | 1 | 1 |
| $\mathbf{4}$ | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 |
| $\mathbf{5}$ | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| $\mathbf{6}$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 6 |
| $\mathbf{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 1 |
| $\mathbf{8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| $\mathbf{9}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TABLE III

| Rectilinear Distance between Equipment |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| From/To | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ |
| $\mathbf{1}$ | 0 | 1 | 2 | 1 | 2 | 3 | 2 | 3 | 4 |
| $\mathbf{2}$ | 1 | 0 | 1 | 2 | 1 | 2 | 3 | 2 | 3 |
| $\mathbf{3}$ | 2 | 1 | 0 | 3 | 2 | 1 | 4 | 3 | 2 |
| $\mathbf{4}$ | 1 | 2 | 3 | 0 | 1 | 2 | 1 | 2 | 3 |
| $\mathbf{5}$ | 2 | 1 | 2 | 1 | 0 | 1 | 2 | 1 | 2 |
| $\mathbf{6}$ | 3 | 2 | 1 | 2 | 1 | 0 | 3 | 2 | 1 |
| $\mathbf{7}$ | 2 | 3 | 4 | 1 | 2 | 3 | 0 | 1 | 2 |
| $\mathbf{8}$ | 3 | 2 | 3 | 2 | 1 | 2 | 1 | 0 | 1 |
| $\mathbf{9}$ | 4 | 3 | 2 | 3 | 2 | 1 | 2 | 1 | 0 |

Their work conducted 19 sets of experiments to determine the appropriate combination of the population size $P$ and generation size $G$. The crossover and mutation probability are taken as 0.7 and 0.8 respectively for all simulations.
Table IV shows the resulting optimal facility layouts giving a total material handling cost of 4818 which was the same value to ones compared in the literature.

TABLE IV
Optimal Solutions

| OPTIMAL SOLUTIONS |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Optimal Solutions | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ |  |
| $\mathbf{1}$ | 4 | 3 | 7 | 8 | 9 | 1 | 5 | 2 | 6 |  |
| $\mathbf{2}$ | 5 | 2 | 6 | 8 | 9 | 1 | 4 | 3 | 7 |  |
| $\mathbf{3}$ | 6 | 2 | 5 | 1 | 9 | 8 | 7 | 3 | 4 |  |
| $\mathbf{4}$ | 7 | 3 | 4 | 1 | 9 | 8 | 6 | 2 | 5 |  |
| $\mathbf{5}$ | 7 | 1 | 6 | 3 | 9 | 2 | 4 | 8 | 5 |  |
| $\mathbf{6}$ | 4 | 8 | 5 | 3 | 9 | 2 | 7 | 1 | 6 |  |
| $\mathbf{7}$ | 5 | 8 | 4 | 2 | 9 | 3 | 6 | 1 | 7 |  |
| $\mathbf{8}$ | 6 | 1 | 7 | 2 | 9 | 3 | 5 | 8 | 4 |  |

The experimental results are shown in Table V and are expressed in terms of the best total material handling cost among trials (Best) and the number of trials needed to obtain one of the optimal solutions (Trials).
The result of the simulation shows that the proposed method is much efficient than the four other approaches presented in the literature. The results show that the proposed method produces most of the optimal solution using 20 trials of any combination of $P$ and $G$.

TABLE V
Optimal Solution Comparison

| Exp. | GA Parameters |  | Proposed Method |  | Ref. [6] |  | Trials | $\frac{\text { Ref. [7] }}{\text { Best }}$ | $\begin{gathered} \hline \hline \text { Ref. [8] } \\ \hline \text { Best } \\ \hline \end{gathered}$ | $\begin{gathered} \hline \hline \text { Ref. [5] } \\ \hline \text { Best } \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | P | G | Trials | Best | Trials | Best |  |  |  |  |
| 1 | 20 | 10 | 20 | 4862 | 4050 | 5119 | 200 | 5039 | 5233 | 4938 |
| 2 | 40 | 10 | 20 | 4818 | 8595 | 5150 | 400 | 4818 | 5040 | 5039 |
| 3 | 100 | 10 | 20 | 4818 | 180 | 4872 | 1000 | 4818 | 4818 | 4938 |
| 4 | 200 | 10 | 20 | 4818 | 405 | 4818 | 2000 | 4818 | 4818 | 4818 |
| 5 | 500 | 10 | 20 | 4818 | 270 | 4818 | 5000 | 4818 | 4818 | 4818 |
| 6 | 20 | 20 | 20 | 4818 | 360 | 4818 | 400 | 4872 | 5225 | 4938 |
| 7 | 40 | 20 | 20 | 4818 | 2160 | 4939 | 800 | 4818 | 4927 | 4992 |
| 8 | 100 | 20 | 20 | 4818 | 1125 | 4990 | 2000 | 4818 | 4818 | 4818 |
| 9 | 200 | 20 | 20 | 4818 | 765 | 4818 | 4000 | 4818 | 4818 | 4818 |
| 10 | 20 | 40 | 20 | 4818 | 1485 | 4818 | 800 | 4818 | 5225 | 4938 |
| 11 | 40 | 40 | 20 | 4818 | 3105 | 4818 | 1600 | 4818 | 4927 | 4992 |
| 12 | 100 | 40 | 20 | 4818 | 990 | 4818 | 4000 | 4818 | 4818 | 4818 |
| 13 | 200 | 40 | 20 | 4818 | 2160 | 4818 | 8000 | 4818 | 4818 | 4818 |
| 14 | 20 | 100 | 20 | 4818 | 3105 | 4818 | 2000 | 4818 | 5225 | 4938 |
| 15 | 40 | 100 | 20 | 4818 | 225 | 4818 | 4000 | 4818 | 4818 | 4927 |
| 16 | 100 | 100 | 20 | 4818 | 2160 | 4818 | 10000 | 4818 | 4818 | 4818 |
| 17 | 20 | 200 | 20 | 4818 | 3015 | 4818 | 4000 | 4818 | 4818 | 4938 |
| 18 | 40 | 200 | 20 | 4818 | 3240 | 4818 | 8000 | 4818 | 4818 | 4862 |
| 19 | 10 | 500 | 20 | 4818 | 3600 | 4818 | 5000 | 4818 | 4818 | 4818 |

# International Journal of Mechanical, Industrial and Aerospace Sciences 

ISSN: 2517-9950
Vol:7, No:8, 2013

## B. Numerical Example 2

TABLE VII
Another example is twelve machines from [16] amount of material flow, the unit material handling cost, an the rectilinear distance between locations of equipment are shown in Tables VI, VII and VIII respectively.

TABLE VI

| Material Flow between Equipment |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| From/To | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0 | 3 | 2 | 2 | 1 | 3 | 0 | 2 | 1 | 4 | 2 | 1 |
| 2 | 3 | 0 | 2 | 3 | 2 | 4 | 1 | 0 | 0 | 3 | 1 | 2 |
| 3 | 2 | 2 | 0 | 1 | 0 | 2 | 2 | 3 | 2 | 0 | 3 | 2 |
| 4 | 2 | 3 | 1 | 0 | 2 | 3 | 3 | 2 | 1 | 0 | 2 | 1 |
| 5 | 1 | 2 | 0 | 2 | 0 | 1 | 3 | 0 | 1 | 2 | 2 | 1 |
| 6 | 3 | 4 | 2 | 3 | 1 | 0 | 2 | 1 | 0 | 3 | 1 | 1 |
| 7 | 0 | 1 | 2 | 3 | 3 | 2 | 0 | 2 | 3 | 0 | 1 | 3 |
| 8 | 2 | 0 | 3 | 2 | 0 | 1 | 2 | 0 | 3 | 2 | 2 | 0 |
| 9 | 1 | 0 | 2 | 1 | 1 | 0 | 3 | 3 | 0 | 2 | 2 | 3 |
| 10 | 4 | 3 | 0 | 0 | 2 | 3 | 0 | 2 | 2 | 0 | 2 | 1 |
| 11 | 2 | 1 | 3 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 0 | 2 |
| 12 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 0 | 3 | 1 | 2 | 0 |


| From/To | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ | $\mathbf{1 0}$ | $\mathbf{1 1}$ | $\mathbf{1 2}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{1}$ | 0 | 6 | 8 | 4 | 7 | 3 | 4 | 11 | 9 | 4 | 7 | 5 |
| $\mathbf{2}$ | 6 | 0 | 5 | 7 | 9 | 4 | 6 | 6 | 3 | 5 | 11 | 8 |
| $\mathbf{3}$ | 8 | 5 | 0 | 6 | 9 | 8 | 12 | 4 | 6 | 8 | 10 | 6 |
| $\mathbf{4}$ | 4 | 7 | 6 | 0 | 4 | 3 | 8 | 6 | 12 | 9 | 7 | 8 |
| $\mathbf{5}$ | 7 | 9 | 9 | 4 | 0 | 6 | 8 | 5 | 10 | 9 | 6 | 8 |
| $\mathbf{6}$ | 3 | 4 | 8 | 3 | 6 | 0 | 5 | 7 | 4 | 8 | 9 | 6 |
| $\mathbf{7}$ | 4 | 6 | 12 | 8 | 8 | 5 | 0 | 7 | 3 | 5 | 10 | 8 |
| $\mathbf{8}$ | 11 | 6 | 4 | 6 | 5 | 7 | 7 | 0 | 4 | 9 | 7 | 5 |
| $\mathbf{9}$ | 9 | 3 | 6 | 12 | 10 | 4 | 3 | 4 | 0 | 6 | 9 | 7 |
| $\mathbf{1 0}$ | 4 | 5 | 8 | 9 | 9 | 8 | 5 | 9 | 6 | 0 | 10 | 6 |
| $\mathbf{1 1}$ | 7 | 11 | 10 | 7 | 6 | 9 | 10 | 7 | 9 | 10 | 0 | 8 |
| $\mathbf{1 2}$ | 5 | 8 | 6 | 8 | 8 | 6 | 8 | 5 | 7 | 6 | 8 | 0 |

TABLE VIII
Rectilinear Distance between Equipment

| From/To | $\mathbf{1}$ | $\mathbf{2}$ | $\mathbf{3}$ | $\mathbf{4}$ | $\mathbf{5}$ | $\mathbf{6}$ | $\mathbf{7}$ | $\mathbf{8}$ | $\mathbf{9}$ | $\mathbf{1 0}$ | $\mathbf{1 1}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{1}$ | 0.0 | 1.0 | 1.8 | 1.5 | 1.2 | 1.4 | 2.0 | 1.3 | 1.6 | 1.5 | 2.0 |
| $\mathbf{2}$ | 1.0 | 0.0 | 2.0 | 1.6 | 1.0 | 1.8 | 1.4 | 1.0 | 1.8 | 1.2 | 1.0 |
| $\mathbf{3}$ | 1.8 | 2.0 | 0.0 | 1.2 | 1.6 | 1.4 | 2.0 | 1.4 | 1.4 | 2.0 | 1.2 |
| $\mathbf{4}$ | 1.5 | 1.6 | 1.2 | 0.0 | 1.5 | 1.0 | 1.4 | 1.6 | 1.0 | 1.6 | 1.4 |
| $\mathbf{5}$ | 1.2 | 1.0 | 1.6 | 1.5 | 0.0 | 1.2 | 2.0 | 1.8 | 1.0 | 2.0 | 1.7 |
| $\mathbf{6}$ | 1.4 | 1.8 | 1.4 | 1.0 | 1.2 | 0.0 | 1.4 | 1.0 | 1.5 | 1.2 | 1.4 |
| $\mathbf{7}$ | 2.0 | 1.4 | 2.0 | 1.4 | 2.0 | 1.4 | 0.0 | 2.0 | 1.2 | 1.4 | 1.0 |
| $\mathbf{8}$ | 1.3 | 1.0 | 1.4 | 1.6 | 1.8 | 1.0 | 2.0 | 0.0 | 2.0 | 1.3 | 1.4 |
| $\mathbf{9}$ | 1.6 | 1.8 | 1.4 | 1.0 | 1.0 | 1.5 | 1.2 | 2.0 | 0.0 | 1.4 | 1.6 |
| $\mathbf{1 0}$ | 1.5 | 1.2 | 2.0 | 1.6 | 2.0 | 1.2 | 1.4 | 1.3 | 1.4 | 0.0 | 2.0 |
| $\mathbf{1 1}$ | 2.0 | 1.0 | 1.2 | 1.4 | 1.7 | 1.4 | 1.0 | 1.4 | 1.6 | 2.0 | 0.0 |
| $\mathbf{1 2}$ | 1.0 | 2.0 | 1.0 | 1.5 | 1.0 | 1.9 | 1.6 | 1.2 | 1.3 | 1.5 | 1.6 |

In this example, the number of individuals and generations increase simultaneously to examine the behavior of optimal solution. The starting parameter of GA is 50 individuals and 50 generations. The crossover and mutation probability are taken as 0.7 and 0.8 respectively for all simulations. The optimal solution is compared in 20 trials. Table IX shows the objective value and the corresponding facility locations at different trials using 50 individuals and 50 generations. The best solution in this case is from trial number 19 which is 2058.2 and the facility locations are shown in Fig. 4.

| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Facility | 11 | 6 | 5 | 12 | 3 | 1 | 4 | 10 | 7 | 8 | 2 | 9 |

Fig. 4 Best Facility Locations for 50 Individuals and 50 Generations

TABLE IX
ObJective Value and Facilities Location for 50 Individuuals and 50 Generations

| Trial | Objective Value | Facility |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 2080.4 | 11 | 2 | 8 | 3 | 4 | 6 | 5 | 10 | 7 | 12 | 1 | 9 |
| 2 | 2091.6 | 12 | 5 | 1 | 11 | 7 | 6 | 4 | 10 | 3 | 9 | 2 | 8 |
| 3 | 2075.0 | 4 | 2 | 12 | 9 | 5 | 11 | 10 | 3 | 8 | 1 | 6 | 7 |
| 4 | 2096.2 | 4 | 1 | 7 | 12 | 2 | 11 | 10 | 3 | 5 | 9 | 8 | 6 |
| 5 | 2081.0 | 1 | 10 | 2 | 12 | 6 | 3 | 9 | 11 | 7 | 8 | 5 | 4 |
| 6 | 2066.0 | 4 | 7 | 10 | 8 | 5 | 11 | 9 | 6 | 1 | 3 | 12 | 2 |
| 7 | 2068.0 | 1 | 8 | 12 | 4 | 3 | 2 | 5 | 6 | 9 | 10 | 7 | 11 |
| 8 | 2092.2 | 9 | 12 | 8 | 2 | 11 | 4 | 10 | 7 | 1 | 5 | 6 | 3 |
| 9 | 2083.6 | 4 | 2 | 10 | 11 | 1 | 3 | 12 | 6 | 9 | 7 | 5 | 8 |
| 10 | 2083.8 | 9 | 12 | 8 | 11 | 6 | 3 | 2 | 7 | 1 | 5 | 4 | 10 |
| 11 | 2086.4 | 1 | 9 | 6 | 2 | 8 | 3 | 7 | 11 | 4 | 5 | 12 | 10 |
| 12 | 2083.8 | 2 | 10 | 12 | 11 | 5 | 1 | 8 | 3 | 4 | 6 | 9 | 7 |
| 13 | 2085.6 | 12 | 5 | 6 | 1 | 2 | 4 | 8 | 7 | 11 | 9 | 10 | 3 |
| 14 | 2089.8 | 12 | 10 | 7 | 11 | 9 | 3 | 1 | 2 | 8 | 6 | 5 | 4 |
| 15 | 2100.8 | 12 | 7 | 10 | 2 | 4 | 6 | 1 | 5 | 11 | 3 | 8 | 9 |
| 16 | 2098.0 | 1 | 3 | 10 | 2 | 11 | 5 | 12 | 6 | 4 | 7 | 9 | 8 |
| 17 | 2068.4 | 3 | 7 | 10 | 1 | 12 | 2 | 8 | 5 | 9 | 4 | 6 | 11 |
| 18 | 2068.4 | 12 | 7 | 10 | 1 | 9 | 2 | 3 | 5 | 8 | 4 | 6 | 11 |
| 19 | 2058.2 | 11 | 6 | 5 | 12 | 3 | 1 | 4 | 10 | 7 | 8 | 2 | 9 |
| 20 | 2102.6 | 8 | 11 | 12 | 2 | 3 | 6 | 5 | 1 | 7 | 10 | 4 | 9 |

The starting parameter of GA is gradually increased by $50 \quad \mathrm{X}$ shows the optimal objective value at different individuals until it reaches 300 for both individuals and generations. Table and generations.

TABLE X
Objective Value at Different Number of Individuals and Generations

| Individual/Generation | $\mathbf{5 0}$ | $\mathbf{1 0 0}$ | $\mathbf{1 5 0}$ | $\mathbf{2 0 0}$ | $\mathbf{2 5 0}$ | $\mathbf{3 0 0}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathbf{5 0}$ | 2058.2 | 2047.4 | 2045.6 | 2046 | 2046 | 2041.8 |
| $\mathbf{1 0 0}$ | 2046.4 | 2046.6 | 2044.4 | 2046.8 | 2041.8 | 2045.2 |
| $\mathbf{1 5 0}$ | 2048.4 | 2045.2 | 2045.2 | 2045.2 | 2043.4 | 2044.4 |
| $\mathbf{2 0 0}$ | 2043.4 | 2045.2 | 2043.4 | 2043.4 | 2040.2 | 2045.2 |
| $\mathbf{2 5 0}$ | 2045.2 | 2041.8 | 2043.4 | 2044.4 | 2041.8 | 2041.8 |
| $\mathbf{3 0 0}$ | 2045.2 | 2041.8 | 2040.2 | 2041.8 | 2040.2 | 2040.2 |

Based on Table X, the optimal solution is 2040.2 and the optimal facility locations are shown in Fig. 5. Fig. 6 shows the graphical representation of how the objective value behaves from an increase of individuals and generations. An increase of generation results to an improved objective value than an increase of individual.

| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Facility | 6 | 4 | 5 | 11 | 2 | 3 | 9 | 7 | 1 | 8 | 12 | 10 |

Fig. 5 Optimal Facility Locations


Fig. 6 Graphical Representation Comparing the Objective Values at Different Individuals and Generations

## V.Conclusion and Future Works

In this paper, we developed a methodology that minimizes total material handling costs using genetic algorithm. The proposed method is much efficient than the four other methods
in the literature as a comparison using benchmark numerical example. The solution shows that an increase in generation results to an improved objective value than in an increase of individual. Although the coding is simple, it shows robustness and generates good solution.

Future work may use the methodology described in this paper to a large number of facilities and apply to real-world case studies. Also, expand the method in multi-constraint and multi-objective optimization problem.

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