Solving Multi Objective Multi Row Fixed Area Cell Layout Problems by Using Relative Importance Factors

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Abstract–An ideal plant layout reduces total manufacturing costs through minimized material handling costs, delay in production, backward movements, and process inventory. Economics in material handling, effective utilization of existing area, minimization of delays in production, improved the product quality, minimum investment on equipment's, eliminate the bottlenecks, better production control and better supervision are the advantages of a good plant layout. The objective of this article is to find out an optimum layout design for compare two nontraditional optimization techniques of objective fixed area multi row cell layout problems. The multi-objectives are minimize the total material handling cost and also minimize the number of backtracking movements. In this article Artificial Bee Colony (ABC) algorithm and Particle Swarm Optimization (PSO) algorithms are used to solve the layout problems. It also compared the results obtained from ABC and PSO techniques and concluded that the PSO algorithm gives better result for the layout problems.

Keywords: Manufacturing system, Cellular layout, artificial bee colony algorithm, particle swarm optimization

I. Introduction

A facility layout is an arrangement of production equipment's, machineries, tools, and furniture in a good manner. James stated that the better layout involves the allocation of space and the arrangement of equipment's minimized overall operating costs. 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 [1]. The advantages of layout design are quickest material flow with lower cost and least amount of material handling. The layout design depends on the product mix and the product volume. There are six types of layout organization referred to, namely Product or Line layout, Process or Functional or Job shop layout, Fixed position or Location or Static layout, Cellular or Group Technology layout, Hybrid or Combined and FMS layout. The machines or equipment's are arranged in one line based on the sequence of operations required for the product as known as product layout. This type is suitable for mass production of standardized products. The advantages of this layout are fewer inventories, minimum material handling, less work in process and small working space.

In process layout, similar machines are arranged together at one place. It is suitable for batch production of not standardized products. Higher machine utilization, greater flexibility, and lower investment are the merits of this layout. In fixed position layout the movement of manpower and machines to the product site which remains stationary. It is preferred for bulky and heavy size products. It has small investment on layout, high adjustment, and great flexibility. Construction of locomotives, ships, boilers, generators, wagon, and aircraft are the examples of this layout. A combination of process and product type layout is known as cellular layout and it uses the Group Technology (GT) principle. The principle of GT is to divide the manufacturing facility into small groups or cells of machines [2]. Each of these cells is dedicated to a specified family or set of part types. The cellular manufacturing is the grouping of the production equipment's into machine cell where each machine cell specializes in the production of a particular part family. GT is a manufacturing philosophy in which similar parts are identified and grouped together to take the advantage of their similarities in design and production. Similar parts are arranged into part families, where each part family possesses similar design and/or manufacturing attributes. A part family is a collection of parts that are similar either in geometric shape and size or in the processing steps required in their manufacturing [3].

Cellular layout problems are families of design problems involving the placement or allocation of work centers, which have given fixed area. The work canters are placed optimally with shorter travelling distance of products. Fixed area cellular layout problems are families of design problems involving the placement or allocation of work centers, which have given fixed area. The work centers are placed optimally with shorter traveling distance of products [4]. The type of the machine layout is affected by a number of factors, namely the number of machines, availability of floor space, part sequences and the material handling systems [5]. Any two or more above said layouts are combined in hybrid layout. FMS layout consists of a group of processing work stations interconnected by means of an automated material handling and storage system and controlled by integrated computer control system. It has the capability of processing a variety of different parts and quantities of production.

There are two types of movements associated with the flow-line layout, which affects the flow of operations, namely, backtracking, and bypassing. Backtracking is the movement of a part from one machine to another that precedes it in the sequence of machines in flow-line arrangement. Backtracking occurs when the parts being processed have different sequence of operations in the flow-line type of arrangement. On the other hand, bypassing occurs when a part skips some machines while it is moving towards the end of a flow line arrangement.

The overview of this article is organized as follows. Literature review is presented in section 2. Section 3 describes the multi-row fixed area cell layout problems. Section 4, explains the relative importance factors. In section 5, multi-objective functions are given. Section 6 explains the proposed approaches. Results are tabulated and discussed in section 7. A section 8 gives suggestion for future research scope and section 9 concludes the article. References are followed by conclusion.

II. Literature review

Some of the conventional and non-conventional methods are used to solve the facility layout problems. In conventional techniques, diagrams and graphs are used to solve the layout problems. Apple done a detailed analysis on the parts routing, parts volume, parts traveling distance, frequency of movement and the cost of the movement for solving layout problems[6]. Assembly charts, from-to charts, multiproduct charts, and string diagrams are the ancient techniques used in layout problems [7].

Genetic Algorithm (GA) is a well-known and powerful stochastic search and optimization technique based on evaluation theory principle. The merits of GA are faster convergent rate and better quality solution. It is having several applications to general optimization and combinatorial optimization problems [8]. Suresh et al used this technique to solve layout problems with the objective of minimizing the material handling cost between the departments [9]. Gupta et al proposed a GA based method to find out the part family and the layout between cells. In his formulation, the arrangement of cell was limited and the actual layout of machines within cells was not considered [10]. An improved GA is implemented by Lee et al to derive solutions for multi-floor facility layout problems [11]. Also, GA is used to solve a multi-objective machine layout problem with unequal area and fixed shape by Balamurugan et al [12].

Simulated Annealing (SA) algorithm is a powerful tool that has ability of local search. It is relatively easy to code, even for complex problems. Venugopal and Narendran presented an algorithm based on SA algorithm to solve the machine-component grouping problem for the design of cells in a manufacturing system [13].

Saravanan and Arulkumar compared GA with SA to find out the better algorithm for solving fixed area layout problems. Finally they concluded the SA algorithm is able to achieve better results than Genetic algorithm with less computational time [14].

The Artificial Bee Colony (ABC) algorithm is a recently introduced real-parameter optimization and global optimization algorithm which is inspired by the foraging behavior of honeybees and it proposed for numerical optimization by Karaboga [15]. It is used for optimizing multivariable functions and it produced better results than the other algorithms like GA, Particle Swarm Inspired Evolutionary Algorithm (PS-EA) etc. Also he compared the performance of ABC algorithm with that of Differential Evolution (DE), and EA for multi-dimensional numeric problems and concluded the performance of ABC algorithm is efficiently employed to solve engineering optimization problems [16]. Karaboga and Basturk used ABC technique for data clustering on benchmark problems and compared ABC technique with other techniques. The results indicate that ABC algorithm is efficient for multivariate data clustering [17]. Kong et al presented a Hybrid ABC (HABC) technique to improve the performance of ABC algorithm for global optimization. A novel search strategy was developed and applied on six benchmark functions with various dimensions. Numerical results demonstrated that the proposed algorithm outperforms the ABC in global optimization problems [18]. Bacanin and Tuba [19] introduced modifications to the ABC algorithm for constrained optimization problems that improved the performance of the algorithm. Modification is based on GA operators. This modified algorithm was tested on 13 benchmark problems. The results were compared with the results of Karaboga and Akay's ABC algorithm, the proposed modified algorithm showed improved performance [20, 21].

Particle Swarm Optimization (PSO) algorithm is a population based stochastic optimization technique, developed for solving continuous and discrete optimization problems. It inspired by social behavior of bird flocking, fish schooling or bees swarming. The system is initialized with a population of random solutions and searches for optima by updating generations by Kennedy and Eberhart [22]. Asokan et al used PSO approach to solve unequal area facility layouts problems with the objective to minimize material flow between facilities and aspect ratios of the facilities. The proposed algorithm performed well than the existing algorithms [23]. Satheeskumar et al used PSO technique for solving the loop layout problem. The clearance between the machines is considered in the design and it helps in choosing the best layout [24]. Ming and Ponnambalam implemented a hybrid search algorithm using GA and PSO for the concurrent design of cellular manufacturing system [25].

III. Problem Description

A benchmark problem (Example 1 i.e. 3Px8M) has been taken from Reis and Anderson's [4] article and one more similar problem (10Px10M) has been taken. ABC and PSO techniques are used to solve the problems. Machine-Part matrix, parts sequence, area of the machines, and area of the layout are the primary required data. The primary data should be included the production data, production center data and total area of the layout. The production data consists of product name, product sequence, and loads/unit time of each product as shown in Table 1. While designing a layout, loads of the product plays an important role.

Table 1: Production data

Production data for Example 1 (3P)		
Product	Sequence	Loads/Unit time
a	1-2-3-6-7-8	40
b	1-2-6-5-4-8	100
c	1-3-4-5-8	25
Production data for Example 2 (10P)		
a	1-2-6-7-8-10	40
b	1-2-6-5-4-10	60
c	1-3-4-5-6-10	100
d	1-2-3-6-7-9-10	50
e	1-2-6-8-4-10	90
f	1-3-5-4-7-10	65
g	1-5-3-6-7-10	45

h	1-8-6-4-10	80
i	1-4-5-9-10	75
j	1-8-3-7-9-10	120

A fixed area layout is different from fixed position layout. In the fixed area layout the length and breadth of the layout are constant. The length and breadth of the layout are 50 x 50 feet. The area of the layout is 2500 square feet. The placement of machines should not affect the layout area. The data to be used in benchmark problem are presented in the above table. For example, 1-2-3-6-7-8 indicates that the product *x* starts from work center-1 and reach work center-8 through passing the work centers-2, 3, 6 and 7. The total number of work centers, name of the work centers and the area of the work centers are the data in the production center data which are shown in Table 2. The area of the individual work centers and total area of the layout are given as square footages. The work centers are arranged in two columns. An aisle is placed in between the two columns. The length of the aisle is equal to the length of the layout. The breadth of the aisle is taken as 10 feet for this problem.

IV. Implementation of Relative Importance Factors

A relative importance factor will be defined as any factor other than volume of product or distance to be moved that is to be considered in determining a good plant layout from a material handling point of view. Importance factors will be used to determine adjustments which will be applied to either the distances to be moved or to the volume of material to be moved.

Table 2: Production Center data

Production Center data for Example 1 (8M)		
Number	Center	Area (Sq. ft)
1	Receiving	200
2	Band saw	300
3	Lathes	100
4	Grinders	400
5	Milling Machines	200
6	Drill processes	200
7	Polishers	400
8	Packaging	200
Production Center data for Example 2 (10M)		
1	Receiving	200
2	Lathe	300
3	Drilling	100
4	Boring	200
5	Shaper	200
6	Planer	200
7	Milling	200
8	Grinding	100
9	Polishing	300
10	Packaging	200

Table 3: Weight importance factors

Example 1			
Factors	Move	Adjust ment	Multi plier
Product priority	Product *b*, 1 to 2	0.4	1.4
	Product *b*, 2 to 6	0.4	1.4
	Product *b*, 6 to 5	0.4	1.4
	Product *b*, 5 to 4	0.4	1.4
	Product *b*, 4 to 8	0.4	1.4
Hazardous	Product *a*, 6 to 7	1.0	2.0
	Product *a*, 7 to 8	1.0	2.0
Directional	Clockwise	1.0	1.0

	Counter-clockwise	1.0	1.2
Example 2			
Product priority	Product *j*, 1 to 8	0.4	1.4
	Product j, 8 to 3	0.4	1.4
	Product j, 3 to 7	0.4	1.4
	Product *j*, 7 to 9	0.4	1.4
	Product *j*, 9 to 10	0.4	1.4
Hazardous	Product *b,* 6 to 5	1.0	2.0
	Product *b,* 5 to 4	1.0	2.0
	Product *f*, 5 to 4	1.0	2.0
	Product *f*, 4 to 7	1.0	2.0
Directional	Clockwise	1.0	1.0
	Anti-clockwise	1.0	1.2

The counter flow is called backtracking. The multiplier value is 1 for clockwise move; the multiplier value is 1.2 for counter clockwise move. A benchmark fixed area layout problem with 8 machines and 3 parts has been taken. There are about 40320 (i.e. 8!) different possible arrangements for 8 machines. Among these possible placements 10 number of machine sequences are selected randomly. The machines (assume the position of machine-1 is fixed) may be placed anywhere and at any position within the cell. While determining the physical location of work centers, it is important to consider some relative importance factors; which affect the layout. The usual factors are volume of product and distance. The others like priority of one product over others, hazardous moves and backtracking moves are too important to consider to the particular product.

The moment value is defined as product of distance value, adjusted load value and multiplier. The distance value is the summation of the distance from the centroid of machine-*i* to the horizontal centre of the aisle, distance from the horizontal centre of the aisle to the centroid of machine-*j*, distance from the centroid of machine-*i* to the centroid of machine-*j*. For example, the distance value of move 1-2 for product *x* is 37.5 (i.e.15+7.5+15), adjusted load value is 40 and the multiplier value is 1. The moment value is 1500 (i.e. 37.5x40x1). Likewise, the moment value is calculated for each move. Sum of the moment values of each move is called total moment value for the particular machine sequence. The total moment value is calculated for 10 sequences which are selected randomly. The 10 sequences are ranked in descending order based on their total moment value. Store the rank-1 sequence as the best which has minimum total moment value. Next, search for another sequence with minimum value. Compare these values and the sequence that gives the minimum value is stored as the best value. Similarly this process is continued up to the termination criteria.

V. Multi-Objective Function

The machine layout problem is the placement of M non-identical machines to N locations in a specified manufacturing area. Due to the predefined sequences of machines for manufacturing multiple products, material handling distance is determined from material flow between machines corresponding to its sequence. The most common objective for designing machine layout is to minimize the total traveling distance of the products or materials and placement or arrangement of machines in the given manufacturing layout.

The objective function (1) is used to determine the physical location of work centres and also to minimize the total traveling distance within the cell. The multi-objectives can be represented as follows:

a) Minimize the Total Traveling Distance, *TTD* = $\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{n=1}^{m}(d_i + d_{ij} + d_j)$ ...(1)
Where, TTD, total traveling distance in feet;
M, number of machines;
m, total number of moves;
d_i, distance from the centroid of machine i to the horizontal center of the aisle;
d_j, distance from the horizontal center of the aisle to the centroid of machine j;
d_{ij}, distance from the centroid of machine i to the centroid of machine j;

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b) Minimize the Total Material Handling Cost,
TMHC = $\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{n=1}^{m} F_{ij}\ C_{ij}\ D_{ij}$ ...(2)
Where, TMHC, total material handling cost per feet in rupees;
F_{ij}, volume of material flow between machine i and machine j;
C_{ij}, material handling cost between machine i and machine j in rupees;
D_{ij}, adjusted distance value (or) distance from the centroid of machine i to the centroid of machine j ($d_i+d_{ij}+d_j$) in feet;

c) Minimize the Total Moment Value, $TMV = \sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{n=1}^{m}(D_{ij}) * (L_{adj}) * (M_{dir})$ ...(3)
where, TMV, total moment value;
$L_{adj,}$ adjusted load value
($V_aM_a + V_bM_b + V_cM_c$);
V_a, V_b, V_c volume of product a, b, c;
M_a, M_b, M_c multiplier value of product a, b, c;
$M_{dir,}$ directional multiplier value;

The adjusted load value ($L_{adj,}$) is defined as the product of the volume of the material moved and the constant adjustment multiplier. This value is constant for all layouts. Each and every move has a separate load value.

VI. Proposed Approaches

6 a Artificial Bee Colony

Tereshko [26], Tereshko and Loengarov [27], and Tereshko and Lee [28] developed a model of foraging behaviour of a honeybee colony. This model consists of food sources, employed bees, and unemployed bees. In this work, an intelligent foraging behaviour of a honey bee is considered. ABC algorithm simulating the behaviour of real honey bees is described for solving multidimensional and multimodal optimization problems.

6 a (i) Pseudo code of ABC algorithm

A pseudo code of ABC algorithm adopted for solving fixed area layout problem is shown in Figure 1.

Define number of bees (*F*), number of cycles (*C*ₙ) and unimproved cycle (*L*)
Initial the population of layouts (X_i); $i = 1, 2, 3, \ldots, F$.
Evaluate the population
Set Cycle = 1
Repeat
- Produce new layouts (V_i) as the employed bees and evaluate them.
- Apply greedy selection process for the employed bees.
- Calculate the probability value (P_i) for layouts.
- Produce new layouts (V_i) as the onlookers from X_i selected depending on P_i and evaluate them.
- Apply greedy selection process for the onlookers.
- Determine the abandoned layout for the scout according to *L*, if exits, replace it with one.
- Update the best achieved so far solution.
- Cycle = Cycle + 1

Until Cycle = C_n

Figure 1 Pseudo code of ABC algorithm

6 a (ii) Control Parameters of ABC algorithm for Example 1

Each instance can be characterized by the following parameters:
Number of jobs/parts, *Np*=3;
Number of machines, *M*=8;
Followings are the detail parameters value:
The size of the population is equal to the number of employed bee and the number of onlooker, which is set to 20**Np*;
Size of the population = Number of colony size = 20**Np* = 20*3 = 60 (employed bees + onlooker bees)
The number of food sources equals the half of the colony size = 60/2 = 30;
Size of the employed bees or onlooker bees, *F* = 30;
The maximum cycle of the algorithm is set to 100**Np***M*;
C_n = Maximum number of cycle = 100**Np***M* = 100*3*8 = 2400;
The limit number of cycles through which no improvement occurs on the food source, then the employed bee becomes a scout bee; the limit number is set to 5**Np***M*;
Limit number, *L* = 5**M***Np* = 5*8*3 = 120;
The percent of scout bee is set to a random number between 0.05 and 0.1;
ϕ_{ij} denotes random number between -1 to 1 = 0.05 to 1.
Similarly the control parameters are selected for other problems i.e. Example 2 and Example 3.

6 b Particle Swarm Optimization Algorithm

Dr. Eberhart and Dr. Kennedy developed a Particle swarm optimization (PSO) algorithm for solving continuous and discrete optimization problems. PSO is a evolutionary computational optimization technique based on the movement and intelligence of swarms looking for the most fertile feeding location. It inspired by social behavior of bees swarming, bird flocking and fish schooling. Among the non-traditional optimization algorithm, PSO gives better results in a faster, cheaper way compared with other methods for some particular size or particular type of problems. In this technique there are few parameters to adjust. It has been used mainly to solve unconstrained, single-objective optimization problems. It has proven both very effective and quick when applied to a diverse set of optimization problems. These algorithms are especially useful for parameter optimization in continuous, multi-dimensional search spaces.

PSO is initialized with the population of random sequences and then searches for optimum by updating new sequences. In the iteration, each sequence from the population is updated by two best values. The first one is the best sequence (fitness) it has achieved so far and stored the fitness value. This value is known as P_{best}. Another best sequence that is tracked by the particle swarm optimizer is the best value, obtained so far by any sequence in the population. This best value is a global best and known as G_{best}. When a sequence takes part of the population as its neighbors, the best value is a local best and is known as L_{best}. After finding the two best values, the sequence updates its velocity and positions. Particles' velocities on each dimension are clamped to a maximum velocity Vmax. If the sum of accelerations would cause the velocity on that dimension to exceed V_{max}, which is a parameter specified by the user. Then the velocity on that dimension is limited to V_{max}.

6 b (i) PSO Algorithm steps

Start
Step 1: Create particle population by randomly assigning
Locations P = (P_1, P_2, P_3, ...P_N) and
Velocities V = (V_1, V_2, V_3,...., V_N);
Step 2: Calculate the fitness of all particles:
F(P) = {F(P_1), F(P_2), F(P_3)........F(P_N)}

Step 3: If the fitness value is less than the best fitness value (P_{best}) in history, set current value as the new P_{best}.
Step 4: Tracking of the particle locations where it had its highest fitness.
Step 5: Choose particle with the best fitness value of all the particles as the G_{best}.
Step 6: Calculate the velocity of each particle by using the equation

$$V_P[]=V_P[]+L_{F1}\times\{ran_1(\ )\times(P_{best}[]-current[])\}+L_{F2}\times\{ran_2(\ )\times(G_{best}[]-current[])\}$$

where,
$V_P[\ ]$ is the particle velocity,
L_{F1} and L_{F2} are learning factors (Ranges 1 to 4),
$ran_1(\ )$, $ran_2(\ )$ random numbers (0 to 1),
current[] = current[] + V_P[],
current[] is the current particle.

Step 7: Each and every particle velocity is not exceeded to a maximum velocity of V_{max}
Step 8: If it reached maximum number of iterations, then terminate.
Else
Go to Step 2.
End

6 b (ii) PSO Control Parameters for Example 1

The number of particles = 10 Numbers (Range 20 – 40)
Maximum velocity, V_{max} = 20
Learning factors, L_{F1} = L_{F2} = 2(Range 0 - 4)
Random numbers $ran_1(\ )$ =0.48; $ran_2()$=0.83(0 – 1)
Number of iterations = 2000(Maximum)

VII. Evaluation of Results

This 'Layout moment ratio' will serve as a way to compare the different proposed layouts if the original layout's moment is always used as the numerator. The larger layout moment ratio is the more desirable layout for all applications.

Table 4: Layout Analysis work sheet for 3Px8M

Move	Adjusted load values (L)	SA Algorithm			ABC Algorithm			PSO Algorithm		
		Distance Values	Material Handlin	Total moment	Distance Values	Material Handlin	Total moment	Distance Values	Material Handlin	Total moment
1 to	180	32.5	14625	5850	32.5	14625	5850	42.5	19125	7650
2 to	40	40	4000	1920	40	4000	1600	40	4000	1600
3 to	40	32.5	3250	1560	32.5	3250	1560	32.5	3250	1560
6 to	80	55	11000	4400	55	11000	4400	45	9000	3600
7 to	80	35	7000	2800	35	7000	2800	45	9000	4320
2 to	140	42.5	14875	7140	42.5	14875	7140	32.5	11375	5460
6 to	140	40	14000	5600	40	14000	5600	40	14000	5600
5 to	140	35	12250	4900	35	12250	4900	45	15750	6300
4 to	140	45	15750	7560	45	15750	7560	35	12250	4900
1 to	25	37.5	2343.75	937.5	37.5	2343.75	937.5	32.5	2031.25	812.5
3 to	25	47.5	2968.75	1425	47.5	2968.75	1425	62.5	3906.25	1875
4 to	25	35	2187.5	1050	35	2187.5	1050	45	2812.5	1350
5 to	25	50	3125	1250	50	3125	1250	40	2500	1000
Total		527.5	107375	46392.	527.5	107375	46072.	537.5	109000	46027.
Layout		53820/46392.5=1.160			53820/46072.5=1.168			53820/46027.5=1.169		

After implementing some non-traditional optimization algorithms to the fixed area cellular layout problem some results are obtained. These results are summarized and tabulated in Table 4 and 5. By using SA, ABC and PSO, total traveling distance of products, total material handling cost, total moment value and layout moment ratio are found for each sequence for the Example problems 1 and 2.

Table 5: Layout Analysis work sheet for 10Px10M

Mov e	Adjuste d load values	SA Algorithm			ABC Algorithm			PSO Algorithm		
		Distanc e	Materia l	Total mome	Distanc e	Materia l	Total mome	Distanc e	Materia l	Total mome
1 to	240	37.5	22500	9000	32.5	19500	7800	32.5	19500	7800
2 to	190	32.5	15438	7410	42.5	20188	9690	42.5	20188	9690
6 to	135	40.0	13500	5400	35.0	11813	5670	55.0	18563	8910
7 to	40	52.5	5250	2100	42.5	4250	2040	62.5	6250	3000
8 to	40	62.5	6250	3000	62.5	6250	2500	47.5	4750	1900
6 to	120	60.0	18000	7200	45.0	13500	6480	35.0	10500	5040
5 to	250	30.0	18750	7500	40.0	25000	10000	40.0	25000	10000
4 to	230	40.0	23000	9200	30.0	17250	6900	35.0	20125	8050
1 to	165	47.5	19594	7837.5	42.5	17531	7012.5	42.5	17531	7012.5
3 to	100	52.5	13125	5250	57.5	14375	5750	47.5	11875	4750
4 to	175	30.0	13125	6300	40.0	17500	8400	40.0	17500	8400
5 to	100	60.0	15000	7200	45.0	11250	4500	35.0	8750	3500
6 to	100	50.0	12500	5000	55.0	13750	6600	40.0	10000	4800
2 to	50	70.0	8750	4200	40.0	5000	2400	40.0	5000	2400
3 to	95	37.5	8906	4275	32.5	7719	3087.5	32.5	7719	3087.5
7 to	218	37.5	20438	9810	37.5	20438	8175	32.5	17713	7085
9 to	293	32.5	23806	9522.5	42.5	31131	14943	42.5	31131	12452.5
6 to	90	42.5	9563	3825	37.5	8438	4050	37.5	8438	4050
8 to	90	72.5	16313	7830	62.5	14063	5625	52.5	11813	4725
3 to	65	52.5	8531	3412.5	47.5	7719	3087.5	37.5	6094	2437.5
4 to	130	50.0	16250	6500	50.0	16250	7800	40.0	13000	5200
7 to	110	40.0	11000	5280	50.0	13750	5500	45.0	12375	4950
1 to	45	70.0	7875	3150	60.0	6750	2700	50.0	5625	2250
5 to	45	52.5	5906	2835	47.5	5344	2565	37.5	4219	2025
1 to	248	32.5	20150	8060	37.5	23250	9300	37.5	23250	9300
8 to	80	42.5	8500	4080	37.5	7500	3000	37.5	7500	3000
6 to	80	60.0	12000	4800	55.0	11000	5280	45.0	9000	4320
1 to	75	70.0	13125	5250	70.0	13125	5250	60.0	11250	4500
5 to	75	42.5	7969	3825	32.5	6094	2437.5	47.5	8906	3562.5
8 to	168	50.0	21000	10080	35.0	14700	5880	35.0	14700	5880
3 to	168	32.5	13650	5460	37.5	15750	6300	57.5	24150	9660
Total		1482.5	429763	184592.	1382.5	420175	180723	1322.5	412413	173737.
Layout		192059/184593=1.040			192059/180723=1.063			192059/173738=1.105		

When compare these values, a highest total moment value is obtained in traditional method. Already GA and SA algorithm results were compared by Saravanan and Arulkumar [16]. When compared with those results, PSO algorithm has produced minimum total moment value. The minimum total moment value indicates the total traveling distance of the product decreased. So the minimum the total moment value is more desirable for designing the layout. While the moments themselves provide the key to path improvement, it is often desired to measure the overall value of a layout in some manner. Perhaps as suitable a way as any is to take the ratio of the total moment for the original or existing layout to the total moment for the proposed layout. In this problem the total moment value of sample layout is t 53820.0 and layout moment ratio is 53820.0/53820.0=1.000. Also it is assumed that the material handling cost per feet is 2.5 rupees. The detailed comparison of total moment value, material handling cost and total moment ratio obtained from various methods for Example 1 and 2 are shown in Table 4 and 5.

Using some non-traditional techniques, different results were obtained and summarized in Table 4 and 5. The differences between the above methods were found out and the best method for the layout design as well. The Figure 2 shows the relations of total moment values that were obtained using various methods. These comparisons have made as graphical representation. The differences between the above methods were found out and the best method for the layout design as well. A 'C Programming Language' was used to develop the coding in the proposed method. A laptop with Intel Core Duo2 @1.66 GHz and 1GB of RAM was used for conducting the experiments and for determining the required computation time.

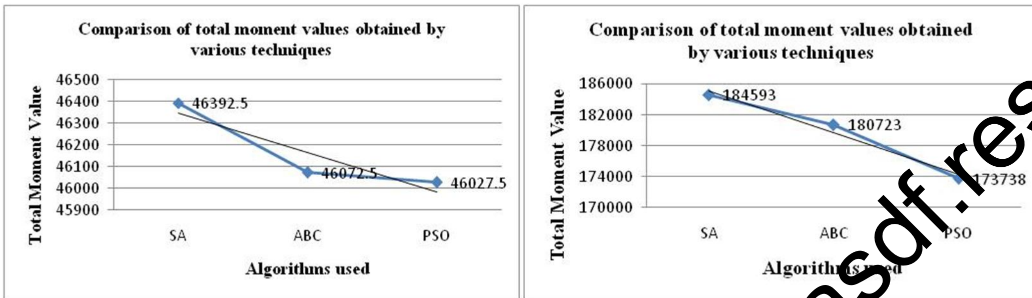

Figure 2 Comparison of total moment value obtained by various algorithms for Ex.1 and Ex.2

SA gives the total moment value is 46392.5 for the new sequence 1 6 5 7 8 4 3 2 and the computation time is 0.60 seconds for 11 iterations. It has slightly higher layout moment ratio 1.160 than GA's ratio. In the application of ABC algorithm, the least total moment value 46072.5 was obtained in 6th iteration about 0.4 seconds. The new sequence is 1 6 5 7 8 4 2 3 with layout moment ration is 1.168. While implementing PSO technique for this bench mark problem, a close to optimum sequence 1 6 5 4 8 7 2 3 was found. The minimum total moment value was 46027.5 for the new sequence obtained in PSO algorithm. This value is lesser than values that have obtained so far. The average computation time is 0.35 seconds in 5th iteration. The layout moment ratio for PSO algorithm is 1.169. This layout moment ratio 1.169 is the larger value than others.

Table 6: Comparison of algorithms based on four main factors for Example1and 2

Problem Size	Comparison factors	Simulated Annealing Algorithm (SAA)	Artificial Bee Colony Algorithm (ABC)	Particle Swarm Optimization (PSO)
3Px8M	Total moment	46392.5	46072.5	46027.5
	Moment ratio	1.16	1.168	1.169
	No. of	11	6	5
	Computation	0.6	0.4	0.35
10Px10M	Total moment	184593.0	180723	173738
	Moment ratio	1.040	1.063	1.105
	No. of	47	28	15
	Computation	1.6	1.0	0.7

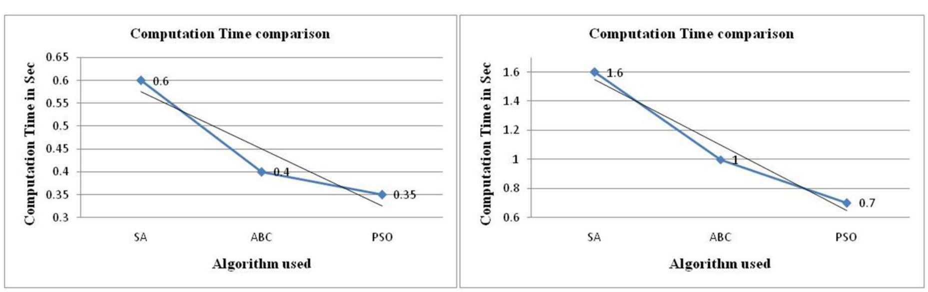

Figure 3 Comparison of computation time for Ex.1 and Ex.2

The comparison of average computation time for each technique is shown in Figure 3. It may be the optimum sequence obtained using the proposed algorithm with minimum computation time. It has higher layout moment ratio about 1.169. The comparison between the moment ratios as shown in Figure 4. In Figure 5, the number of iterations for getting the optimum result is compared for various algorithms. The maximum number of iterations 11 is for SA and minimum is 5 for PSO algorithm. Figure 6 indicates the number of back tracking i.e. reverse direction, movements in various algorithms. The number of back tracking movement is 5 while using PSO algorithm, but it has minimum total moment value. The conclusion of this article is that PSO technique may be the better non-traditional optimization algorithm for designing fixed area cellular layout than SA, and ABC.

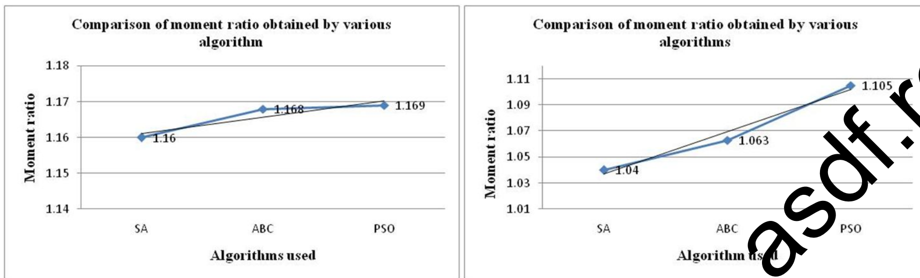

Figure 4 Comparison of layout moment ratio for Ex.1 and Ex.2

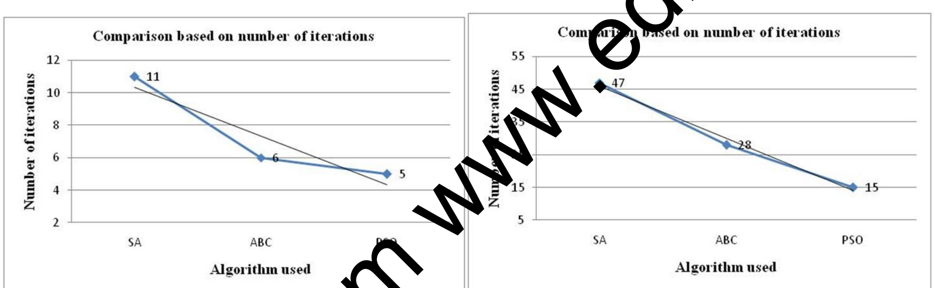

Figure 5 Comparison based on number of iterations for Ex.1 and Ex.2

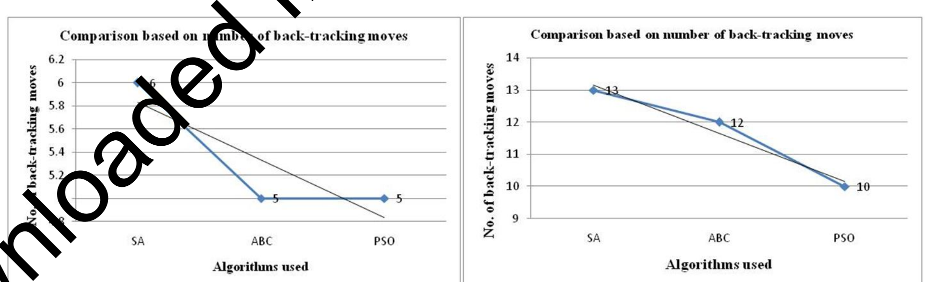

Figure 6 Comparison based on number of back tracking movements for Ex.1 and Ex.2

So PSO is a suitable technique for finding solutions to fixed area cellular layout problems in less time based on total moment value and layout moment ratio. In other hand, SA method produced minimum value in the total traveling distance and also material handling cost. Because the number of back tracking movements are more in the layout obtained by PSO method.

VIII. SCOPE of Potential

In this article, only one cell considered and it can be implemented in multiple cells also. It leaves scope for future research leading to further improvement in optimization area. Ant Colony, Memetic algorithm, Swarm Intelligence, Scatter Search, and Taboo Search techniques are used in order to optimize and converge to the results nearer to optimum. In this work, other factors that are affecting the layout design like product volume, lead-time, material handling system and manufacturing cost may be considered. Also the problem size i.e. number of machines and number of parts may be increased. Because of coding in C language is very complicated, it is recommended for coding with other programming languages such as Java, Visual Basic etc. for large size problems.

X. Conclusion

The main objective of this article is to identify a suitable non-traditional optimization algorithm for fixed area cellular layout problems. Particle Swarm Optimization is able to achieve better results than SA and ABC. PSO has been recognized as an evolutionary computation technique and evolution strategy. The algorithm proposed in this article can be suitably modified to large number of parts with different sequences and large number of machines with fixed area. This method is suitable for large size problems. This system gives best placement of machines in few seconds. This article concluded that the PSO is a better non-traditional optimization algorithm recommended for designing fixed area cellular layout than SA and ABC. Also PSO is the technique used to solve the layout problems in less computation time. It is more simple and robust and it has taken few lines of code and requires only specification of the problem and a few parameters in order to solve it. SA is better method when considered the material handling cost.

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