Revolutionary Optimization Algorithms for solving Fixed Area Loop layout Problems

P.V. Arulkumar[1*], J. Vivek[2], V. Kannadhasan[2], S. Nagarajan[3] and M. Saravanan[4]

[1]*Department of Mechanical Engineering, Bharath Niketan Engineering College Aundipatty 625 536, Tamilnadu, India*

[2]*Department of Mechanical Engineering, Solamalai College of Engineering, Madurai 625 020, Tamilnadu, India*

[3]*Department of Mechanical Engineering, Pandian Saraswathi Yadav Engineering College, Sivagangai 630 561, Tamilnadu, India*

[2]*Department of Mechanical Engineering, Ponjesly College of Engineering Parvathipuram 629 003, Tamilnadu, India*

[1*]*arulkumarveera@gmail.com,* [2]*vivekdynamech18@gmail.com,* [3]*arsnagarajan@gmail.com,*[4]*drmsaravanan@yahoo.com*

Abstract

Arrangement of production equipments within the cell in the given layout is very important task in any manufacturing systems. This paper deals with the design of fixed area loop layout problems in cellular manufacturing. The objective functions are finding the placement of machines within the cell by reducing product total travelling distance, to reduce the total material handling costs, total moment value, and number of back tracking movements. This paper compares the results of non- traditional optimization techniques and finds the optimum technique. Finally it concluded that PSO technique performed well for solving the fixed area loop layout problems.

Keywords: *Artificial Bee Colony, Cellular Layout, Layout Moment Ratio, Particle Swarm, Relative Importance Factors, Simulated Annealing.*

1. Introduction

A good design of facility layout decreases the manufacturing lead time, and improves the efficiency and productivity of the plant [1]. A better layout design contributes in achieving high productivity in the cellular manufacturing system. It was calculated that about 15-70% of the total manufacturing costs are spent for material handling [2]. A good layout reduces total manufacturing costs by 10-30% [3]. In any manufacturing system, the design of layout has an impact on the manufacturing time and the cost [4]. The quick material flow with lower cost and least amount of material handling are the merits of good layout. The layout design depends on the mix and volume of the product. There are three common types of layout organization referred to, namely product or assembly line layout, process or functional or job shop layout, and fixed position or location or static layout.

Cellular or group technology (GT) layout, hybrid or mixed model assembly line or combined layout and flexible manufacturing system (FMS) layout are the hybrid types of layout used. In line or layout, activities are arranged in a line based on the operation sequences. Process layout is sometime called as functional layout, in which manufacturing operations are grouped together on the basis of the function, technology, or equipment used. Fixed-Position layouts, the product remains stationary, but the man, materials, machinery, and other resources are brought to the yard. In cellular layouts, dissimilar machines are grouped into machine cell, to process parts with similar geometry or manufacturing requirements. This layout combines the flexibility of a process layout and the efficiency of a product layout. Any two or more above said layouts are combined in hybrid layout.

2. Review of literature

Obtained an optimal layout by using genetic algorithm (GA) and also reduced the traveling distance by determined the shortest path [5]. A mathematical model was developed by Ariafar et al for solving layout problems in cellular manufacturing systems (CMS). This model reduced the total material handling cost for inter and intra-cell moves [6]. Satheeshkumar et al solved loop layout problems by using PSO technique. This method was com- pared with bench mark problems. The clearance between the ma- chines was considered in the design of loop layout problem [7]. Sha and Chen developed a new tool to resolve the facility layout problems. This tool combined both quantitative and qualitative objectives [8]. Keivani proposed a SA technique to solve multi- floor facility layout problems by minimizing the material handling and rearrangement costs [9]. Christu Paul proposed a PSO technique and derived better solutions for un equal area facility having inner walls and passages. The objective was to reduce material flow between facilities by satisfying some constraints [10]. Iterative Heuristic Algorithm and Branch and Bound Algorithm developed for finding an optimal location of clusters on different levels. It was proposed for grouping highly related departments for both the methods [11]. Tavakoli-Moghadam formulated model concerning inter and intra-cell cost in layout problems in CMS. The objective of the model was to reduce the total cost incurred by the inter and intra-cell movements [12]. SA algorithm developed by Venugopal and Narendran to solve the machine-component grouping problem for the cell design in a manufacturing system [13]. GA with SA compared to find the better algorithm to solve fixed area layout problems. That paper concluded that the SA algorithm has given better results than GA with less computational time [14].

The ABC algorithm is a real-parameter and global optimization algorithm which is inspired by the foraging behavior of honeybees and it was proposed for numerical optimization by Karaboga [15]. Bacanin and Tuba [16] implemented a ABC algorithm for solving optimization problems with constrains. Modification is based on GA operators and it was tested on 13 benchmark problems. The results were compared with the results of Karaboga and Akay's ABC algorithm, and it showed improved performance [17, 18]. PSO is a population based stochastic optimization technique, formulated to resolve discrete and continuous optimization problems. PSO is started with a pool of random solutions and searching for good solution by updating new solutions by Kennedy and Eberhart [19]. PSO approach used to solve unequal area facility layouts problems with the objective to reduce the flow of materials between facilities and facilities aspect ratios and the approach performed well than the existing algorithms [20]. A hybrid search algorithm using GA and PSO was implemented by Ming and Ponnambalam for the concurrent design of CMS [21]. A new model formulated by Wang et al to solve inters and intra-cell layout problems in CMS and also it reduce material handling distance. The comparison concluded that the improved SA produced the same quality solutions in less computation time [22]. Parames Chutima proposed a GA based model to solve layout problems with un equal departmental areas and different geometric shape constraints [23]. Volker Schnecke and Oliver Vornberger proposed a GA based technique for solving selected combinatorial optimization problems [24].

3. Proposed approaches – Simulated annealing algorithm

Simulated annealing is a probabilistic meta-algorithm for global optimization. This algorithm inspired by metals crystallizes in annealing process. It stimulate the cooling process by slowly reduce the temperature until it converges to a 'frozen' state [25].

3.1 Control parameters of SA for problem 1

Starting Temperature = 1000°C; Final Temperature = 0°C;
Temperature decrement = 100°C; Iterations at each temperature - 2000 for low temperature - 1000 for high temperature; Cmax=320; Rmax=64; T=32; α=0.9; β=0.8

4. Artificial bee colony

ABC algorithm simulating an intelligent foraging behaviour of a honey bee and it is developed for solving multi-dimensional and multi-modal optimization problems. The employed bees, onlookers bees, and scouts are the three groups of bees in each colony. The colony consists of 50% of employed bees and rest 50% of onlookers bees. The number of employed bees and the number of food sources are equal in number. When the food source discarded, then the employed bees become a scout bee [26].

4.1 Control parameters of ABC algorithm

The following parameters are used in ABC algorithm for Problem 1:
Total number of products, Np=3, Total number of machines, M=8,
The population size is number of employed bees with onlooker bees, 20*Np;
Size of the population = Number of colony size = 20*Np = 20*3 = 60 (employed bees + onlooker bees); The number of food sources is equal to 50% of the colony = 60/2 = 30;
Size of the employed bees or onlooker bees, F = 30;
The maximum number of cycles for the algorithm is set to 100*Np*M;
C_n = Maximum number of cycles = 100*Np*M = 100*3*8 = 2400;
The employed bee becomes a scout bee when there is no improvements on the food source; the limit number, L = 5*Np*M = 5*3*8 = 120;
The percent of scout bee is between 0.05 to 0.1; denotes random number between -1 to 1 = 0.05 to 1.
Similarly the control parameters are selected for other problems i.e. Problem 2 and Problem 3.

5. Particle swarm optimization algorithm

The PSO technique is inspired by social behaviour observed in swarms of bees, flocks of birds or schools of fish. It is an algorithm based on a social-psychological metaphor

[27]. It is started with the pool 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 found so far and stored the fitness value. This fitness value is P_b (P_{best}). A new best sequence gives the best value than the value obtained so far. The new best value is a global best, G_b (G_{best}). When a sequence takes part of the population as its neighbors, the best value is known as local best, L_b (L_{best}). The sequence updates its velocity and positions for the two best values. The velocity of the particles is limited to V_{max}..

5.1 PSO Control Parameters for Problem 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)
Based on these other control parameters are selected for another two problems.

6. Objective functions

The machine layout problem is the arrangement of M number of dissimilar production equipments to N number of locations in a given layout area. The universal objective to design a layout is to reduce the total traveling distance of the products or materials by better placement of machines in the given manufacturing layout. The objectives can be represented as follows:

Minimize TTD = $\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{j=1}^{m}(d_i + d_{ij} + d_j)$ (1)

where,
TTD, total traveling distance in feet;M, number of machines; m, total number of moves;
d_i, distance between the centroid of machine i to the horizontal center of the aisle;
d_j, distance between the horizontal center of the aisle to the centroid of machine j;
d_{ij}, distance between the centroid of i^{th} machine to the centroid of j^{th} machine;

Minimize TMHC = $\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{j=1}^{m} F_{ij} \; C_{ij} \; D_{ij}$ (2)

where,
TMHC, total material handling cost per feet in rupees; F_{ij}, volume of material flow between machine i and j;
C_{ij}, material handling cost between machine i and j in rupees; D_{ij}, adjusted distance value = (d_i+d_{ij}+d_j) in feet;

Minimize TMV = $\sum_{i=1}^{M}\sum_{j=1}^{M}\sum_{j=1}^{m}(L_{adj}) * (D_{ij}) * (M_{dir})$ (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 product of the adjustment multiplier value and volume of the product. Each move has its own load value.

7. Fixed area loop layout problems

A benchmark problem i.e. Problem 1 with 3 parts and 8 machines has been taken from Reis and Anderson's [28] paper and two more large dimension problem i.e. Problem 2 and 3 with 10 parts and 10 machines and 20 parts with 12 machines has been taken.

Table 1. Production data

Production data for Problem 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 Problem 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
Production data for Problem 3 (20P)		
a	1-2-6-7-8-10-12	40
b	1-2-6-5-4-11-12	100
c	1-3-4-5-6-12	25
d	1-2-3-6-7-9-12	50
e	1-2-6-5-4-8-11-12	90
f	1-3-5-4-7-10-12	30
g	1-5-3-6-7-8-12	45
h	1-8-6-5-4-10-12	60
i	1-4-5-9-11-12	75
j	1-8-3-6-7-9-12	40
k	1-6-8-5-4-7-12	55
l	1-4-5-10-11-12	35
m	1-2-5-6-4-7-12	65
n	1-9-10-7-8-12	95
o	1-8-6-7-11-5-12	150
p	1-4-6-10-8-12	20
q	1-8-11-10-7-9-12	35
r	1-9-6-5-4-10-12	45
s	1-2-3-4-5-6-11-12	50
t	1-2-6-8-10-11-12	40

Table 2. Production Center data

Production Center data for Problem 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 Problem 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
Production Center data for Problem 3 (12M)		
1	Receiving	200
2	Power saw	300
3	Lathe	100
4	Drilling	200
5	Tapping	100
6	Boring	200
7	Shaper	200
8	Planer	100
9	Milling	200
10	Grinding	200
11	Polishing	100
12	Packaging	300

The production data for three problems are tabulated in Table 1. While designing a cell layout, loads of the product plays an important role. In this problem the length of the two columns should be same and breadth of the work centre must be 20 feet. The length of the aisle is equal to the length of the column and breadth of the aisle should be 10 feet. Aisle should be placed between the two columns of machines. Assume that the placement of the work centre-1 is always in first position. In problem 2, the operation sequence of the product *d* is 1-2-3-6-7-9-10. It indicates that the product *d* starts from 1st work center and reached 10th work center passing through 2nd, 3rd, 6th, 7th and 9th work centres. The production center data which shown in Table 2, includes the total number, name and area of the work centers. A Square feet is the unit for area of the individual work center and area of the layout. The work centers are arranged in two columns. An aisle is placed in between the two columns.

7.1 Implementation of relative importance factors

Relative importance factors will be used to determine adjustments which will be applied to either distances to be moved or volume of material to be moved.

Table 3. Weight Importance Factors

Problem 1			
Factors	**Move**	**Adjustment**	**Multiplier**
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 (Same for Pro 1 & 2)	Clockwise	1.0	1.0
	Counter-clockwise	1.0	1.2
Problem 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
Problem 3			
Product priority	Product *o*, 1 to 8	0.4	1.4
	Product *o*, 8 to 6	0.4	1.4
	Product *o*, 6 to 7	0.4	1.4
	Product *o*, 7 to 11	0.4	1.4
	Product *o*, 11 to 5	0.4	1.4
	Product *o*, 5 to 12	0.4	1.4
Hazardous	Product *i,* 5 to 9	1.0	2.0
	Product *i,* 9 to 11	1.0	2.0
	Product *p*, 4 to 6	1.0	2.0
	Product *p*, 6 to 10	1.0	2.0
	Product *p*, 10 to 8	1.0	2.0

Referring to problem 3, the product *o* is the most stable i.e. product *o* has more volume than the others. It based on demand and sales. So relatively higher priority has assigned to this product moves. It is decided that a move of product *o* should be considered 1.4 times as important as a move of other products as shown in Table 3. Likewise in the problem 2, the products *b* and *f* has some radioactive materials in it at machine center 4, 5, 6 and 4, 5, 7 respectively. So it is considered as very important moves in the above said machines. Adjustment 1.0 will be added to the base value. Finally the multiplier value of the product *b* and *f* is 2.0. A minimum distance should be maintained between the work centers. A higher adjustment value 1.0 is added to the base 1.0 value for those moves. In this problem, clock wise moves are considered as normal flow. For any layout design, the counter flow move is always undesirable. The counter flow move is called backtracking move. The multiplier value is 1 for clockwise and 1.2 for anti clockwise moves.

8. Discussion on results

The moment value is product of distance between the work centers, adjusted load value, and the multiplier value. 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.

Table 4. Layout Analysis work sheet for Problem 1 (3Px8M)

SA (1 6 5 7 8 4 3 2)			ABC (1 6 5 7 8 4 2 3)			PSO (1 6 5 4 8 7 2 3)		
Distance Values (D)	Material Handling cost	Total moment	Distance Values (D)	Material Handling cost	Total moment	Distance Values (D)	Material Handling cost	Total moment
32.5	11700	5850	32.5	11700	5850	42.5	15300	7650
40	4800	1920	40	3200	1600	40	3200	1600
32.5	3900	1560	32.5	3900	1560	32.5	3900	1560
55	8800	4400	55	8800	4400	45	7200	3600
35	5600	2800	35	5600	2800	45	10800	4320
42.5	17850	7140	42.5	17850	7140	32.5	13650	5460
40	11200	5600	40	11200	5600	40	11200	5600
35	9800	4900	35	9800	4900	45	12600	6300
45	18900	7560	45	18900	7560	35	9800	4900
37.5	1875	937.5	37.5	1875	937.5	32.5	1625	812.5
47.5	3562.5	1425	47.5	3562.5	1425	62.5	4687.5	1875
35	2625	1050	35	2625	1050	45	3375	1350
50	2500	1250	50	2500	1250	40	2000	1000
528	103113	46393	528	101513	46073	538	99338	46028
53820/46392.5=1.160 (LMR)			53820/46072.5=1.168 (LMR)			53820/46027.5=1.169 (LMR)		

The Layout moment ratio is used to compare the different proposed layouts. The layout which has larger layout moment ratio is always more desirable layout than others. Relative importance factors like product priority, hazardous are implemented. Three problems are solved by using SA, ABC and PSO.

Table 5. Layout Analysis work sheet for Problem 2 (10Px10M)

SA (1 6 3 9 5 4 10 7 2 8)			ABC (1 8 3 7 5 4 10 9 6 2)			PSO (1 8 3 5 4 7 9 10 6 2)		
Distance Values (D)	Material Handling cost	Total moment	Distance Values (D)	Material Handling cost	Total moment	Distance Values (D)	Material Handling cost	Total moment
37.5	18000	9000	32.5	15600	7800	32.5	15600	7800
32.5	18525	7410	42.5	24225	9690	42.5	24225	9690
40.0	10800	5400	35.0	14175	5670	55.0	22275	8910
52.5	4200	2100	42.5	5100	2040	62.5	7500	3000
62.5	7500	3000	62.5	5000	2500	47.5	3800	1900
60.0	14400	7200	45.0	16200	6480	35.0	12600	5040
30.0	15000	7500	40.0	20000	10000	40.0	20000	10000
40.0	18400	9200	30.0	13800	6900	35.0	16100	8050
47.5	15675	7837.5	42.5	14025	7012.	42.5	14025	7012.5
52.5	10500	5250	57.5	11500	5750	47.5	9500	4750
30.0	15750	6300	40.0	21000	8400	40.0	21000	8400
60.0	18000	7200	45.0	9000	4500	35.0	7000	3500
50.0	10000	5000	55.0	16500	6600	40.0	12000	4800
70.0	10500	4200	40.0	6000	2400	40.0	6000	2400
37.5	10688	4275	32.5	6175	3087.	32.5	6175	3087.5
37.5	24525	9810	37.5	16350	8175	32.5	14170	7085
32.5	19045	9522.5	42.5	37358	14943	42.5	24905	12453
42.5	7650	3825	37.5	10125	4050	37.5	10125	4050
72.5	19575	7830	62.5	11250	5625	52.5	9450	4725
52.5	6825	3412.5	47.5	6175	3087.	37.5	4875	2437.5
50.0	13000	6500	50.0	19500	7800	40.0	10400	5200
40.0	13200	5280	50.0	11000	5500	45.0	9900	4950
70.0	6300	3150	60.0	5400	2700	50.0	4500	2250
52.5	7087.5	2835	47.5	6412.5	2565	37.5	5062.5	2025
32.5	16120	8060	37.5	18600	9300	37.5	18600	9300
42.5	10200	4080	37.5	6000	3000	37.5	6000	3000
60.0	9600	4800	55.0	13200	5280	45.0	10800	4320
70.0	10500	5250	70.0	10500	5250	60.0	9000	4500
42.5	9562.5	3825	32.5	4875	2437.	47.5	7125	3562.5
50.0	25200	10080	35.0	11760	5880	35.0	11760	5880
32.5	10920	5460	37.5	12600	6300	57.5	19320	9660
1483	407247	184592	1383	399405	18072	1323	373792	173737
192059/184593=1.040 (LMR)			192059/180723=1.063 (LMR)			192059/173738=1.105 (LMR)		

Table 6. Layout Analysis work sheet for Problem 3 (20Px12M)

SA (1 8 5 6 10 11 9 3 12 7 4 2)			ABC(1 6 5 4 3 9 11 12 10 7 8 2)			PSO (1 8 7 4 11 3 9 10 12 5 6 2)		
Distance Value (D)	MHC Rs.	Total moment	Distance Value (D)	MHC Rs.	Total moment	Distance Value (D)	MHC Rs.	Total moment
32.5	28275	14137	32.5	28275	14137	32.5	28275	14137.5
47.5	38475	15390	37.5	30375	12150	42.5	34425	13770
35	26950	13475	40	30800	15400	30	34650	13860
52.5	28350	11340	37.5	13500	6750	37.5	20250	8100
52.5	8400	4200	47.5	11400	4560	67.5	10800	5400
37.5	13125	6562.	42.5	22312.5	8925	42.5	14875	7437.5
37.5	33187.5	13275	37.5	22125	11062	37.5	33187.5	13275
32.5	24700	12350	37.5	28500	14250	32.5	37050	14820
52.5	15750	6300	52.5	10500	5250	37.5	7500	3750
30	23400	11700	35	27300	13650	30	23400	11700
77.5	8525	4262.	62.5	6875	3437.	67.5	7425	3712.5
62.5	9375	4687.	37.5	8437.5	3375	42.5	9562.5	3825
32.5	18037.5	7215	37.5	20812.5	8325	32.5	12025	6012.5
37.5	10500	5250	37.5	15750	6300	37.5	10500	5250
47.5	2375	1187.	62.5	3125	1562.	47.5	3562.5	1425
75	22500	9000	55	16500	6600	65	19500	7800
57.5	23287.5	9315	52.5	21262.5	8505	52.5	14175	7087.5
50	18750	7500	50	18750	7500	60	15000	7500
37.5	9375	4687.	32.5	8125	4062.	42.5	10625	5312.5
37.5	10125	4050	42.5	7650	3825	47.5	12825	5130
60	15000	7500	65	24375	9750	55	13750	6875
65	5850	2340	45	4050	1620	45	2700	1350
40	18000	7200	35	10500	5250	40	18000	7200
35	3150	1260	40	3600	1440	60	3600	1800
42.5	3825	1912.	47.5	4275	2137.	52.5	4725	2362.5
65	5850	2925	45	4050	2025	45	6075	2430
60	19200	9600	60	28800	11520	55	17600	8800
37.5	25875	12937	42.5	29325	14662	37.5	25875	12937.5
42.5	22950	11475	32.5	26325	10530	37.5	20250	10125
45	14175	5670	35	7350	3675	50	10500	5250
45	20700	10350	55	25300	12650	55	25300	12650
62.5	18750	9375	52.5	15750	7875	52.5	23625	9450
37.5	16875	6750	37.5	11250	5625	42.5	19125	7650
70	5600	2800	50	6000	2400	60	4800	2400
50	5500	2750	40	4400	2200	45	4950	2475
42.5	12112.5	4845	32.5	6175	3087.	37.5	10687.5	4275
35	3850	1925	35	5775	2310	45	4950	2475
42.5	15300	6120	52.5	18900	7560	47.5	11400	5700
47.5	3325	1662.	42.5	2975	1487.	52.5	5512.5	2205
37.5	5625	2812.	47.5	10687.5	4275	42.5	9562.5	3825
40	7800	3120	45	8775	3510	50	9750	3900

35	4550	2275	45	5850	2925	40	7800	3120
75	21000	10500	70	19600	9800	75	21000	10500
45	12825	5130	40	7600	3800	30	5700	2850
35	9100	4550	40	10400	5200	60	23400	9360
42.5	26775	10710	57.5	36225	14490	47.5	19950	9975
55	34650	13860	60	37800	15120	40	16800	8400
55	23100	11550	50	21000	10500	40	25200	10080
35	2100	840	45	2700	1080	40	1600	800
40	1600	800	50	2000	1000	60	3600	1440
52.5	3150	1260	47.5	1900	950	67.5	4050	1620
37.5	3937.5	1575	47.5	3325	1662.	42.5	2975	1487.5
55	7425	2970	60	8100	3240	60	5400	2700
47.5	4750	2375	67.5	6750	3375	47.5	7125	2850
2538	777738	34961	2488	774263	34836	2543	756950	340623
363140/349610= 1.038(LMR)			363140/348360= 1.042(LMR)			363140/340622.5= 1.066(LMR)		

Results obtained by using these algorithms are tabulated for the problem 1, 2, 3 in the table 4, 5, 6 respectively. 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 success sequence for the problem 1, 2 and 3. While comparing these values, a highest total moment value is obtained in SA result. Already GA and SA algorithm results were compared by Saravanan and Arulkumar and they concluded the SA result was better than the GA result for the problem 1[14]. 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. In this problem the total moment value of sample layout is 363140.0 for the problem 3 and layout moment ratio is 363140/363140=1.0. Also it is assumed that the material handling cost per feet is 2 rupees for clockwise moves and 2.5 rupees for anti-clockwise moves. The detailed comparison of total moment value, material handling cost and total moment ratio obtained from various methods for problem 1, 2 and 3 are shown in table 4, 5 and 6.

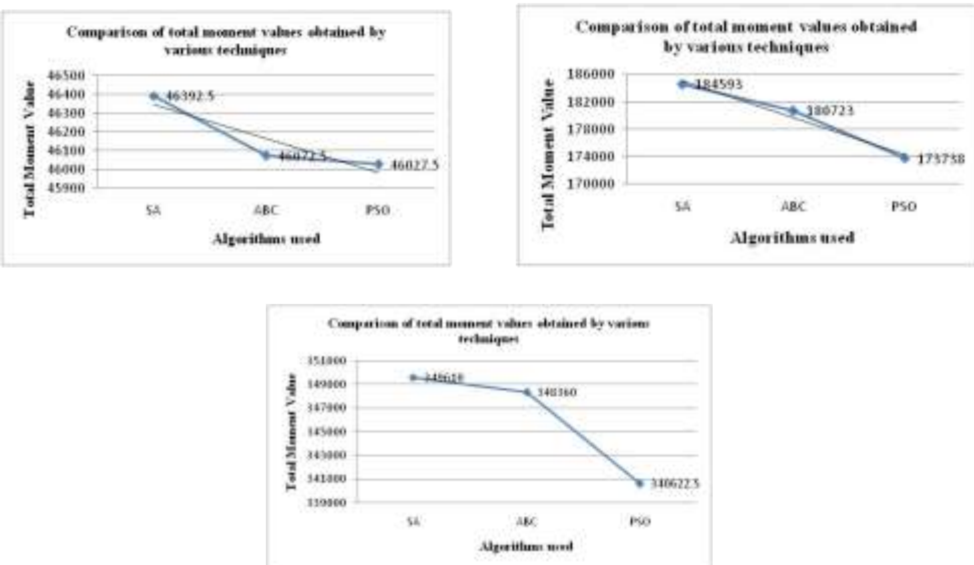

Figure 1, 2, 3. Comparison of total moment value for Problem 1, 2 and 3

The results which are obtained from the above methods are compared and analyzed. The Figure 1, 2 and 3 show the comparison of total moment values that were obtained using various techniques for the problem 1, 2 and 3. These comparisons have made as graphical representation**.**

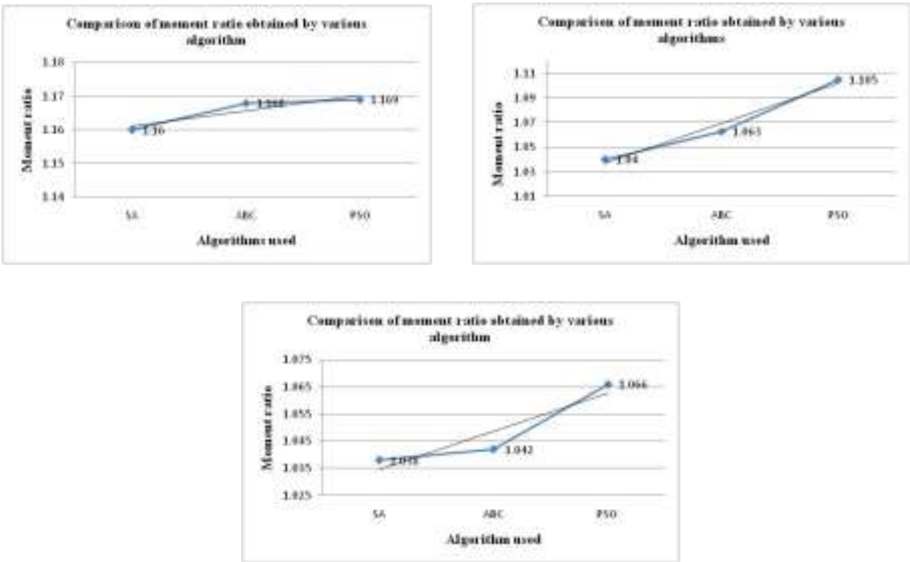

Figure 4, 5, 6. Comparison of LMR for Problem 1, 2 and 3

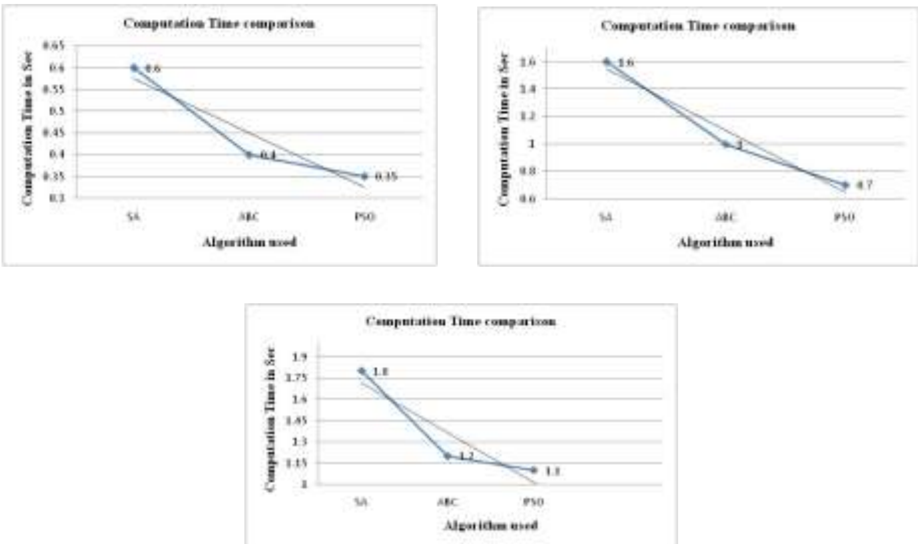

Figure 7, 8, 9. Comparison of CT for Problem 1, 2 and 3

Referring problem 2, SA gives 184592.5 as total moment value for the sequence 1 6 3 9 5 4 10 7 2 8 and the computation time is 1.6 seconds for 47 iterations with the layout moment ratio 1.040. In the application of ABC algorithm, the least total moment value 180723 was obtained in 28th iteration about 1.0 second. The new sequence is 1 8 3 7 5 4 10 9 6 2 with layout moment ration is 1.063. While implementing PSO technique for this problem 2, a close to optimum sequence 1 8 3 5 4 7 9 10 6 2 was found. The minimum total moment value was 173737.5 for the new sequence obtained in PSO algorithm. This value is lesser than values that have obtained so far. The average computation time (CT) is 0.7 second in 15th iteration. The layout moment ratio (LMR) for PSO algorithm is

1.105. This layout moment ratio 1.105 is the larger value than others as shown in Figure 4, 5 and 6.

The comparison of computation time for each technique is shown in Figure 7, 8 and 9. It may be the optimum sequence obtained using the proposed algorithm with minimum computation time. It has higher layout moment ratio about 1.105. The comparison between the moment ratios is shown in Figure 4, 5 and 6. In Figure 10, 11 and 12, the number of iterations for getting the optimum result is compared for various algorithms. The maximum number of iterations (NoI) for problem 3, 52 is for SA and minimum is 23 for PSO algorithm.

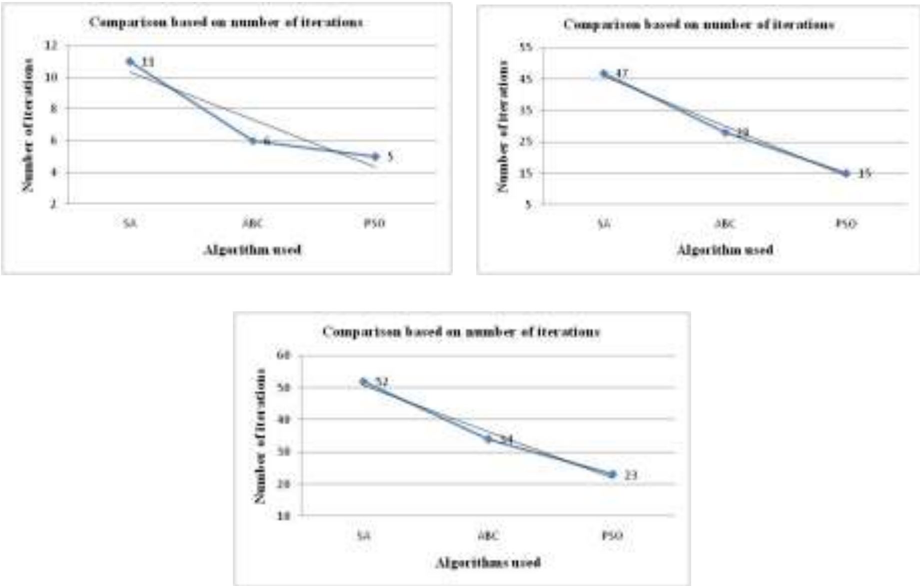

Figure 10, 11,12. Comparison based No. of Iteration for Problem 1, 2 and 3

Figure 14, 15 and 16 indicate the number of back tracking i.e. reverse direction, movements in various algorithms. The number of back tracking movement (BTM) for the problem 3 is 23 while using PSO algorithm, but it has minimum total moment value.

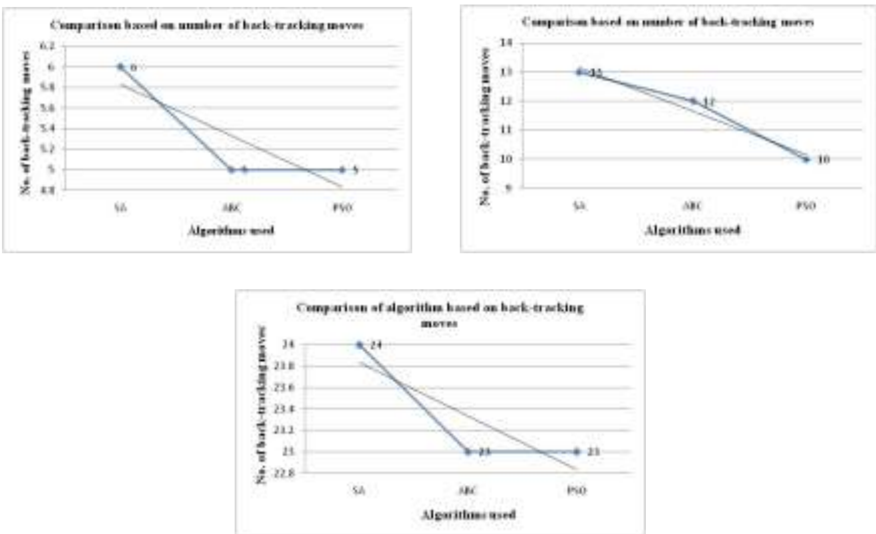

Figure 13, 14, 15. Comparison based on BTM for Problem 1, 2 and 3

So PSO is a suitable technique for finding solutions to fixed area cell layout problems in less time based on total moment value and layout moment ratio. This article concluded that the PSO is a better non-traditional optimization algorithm recommended to design and optimization of fixed area cell layout than SA and ABC.

9. Conclusion

The objectives of this article are to minimize the traveling distance of the products, to reduce the material handling cost and to decrease the total moment values by better placement of machines in the fixed area loop layout problems by using a non-traditional optimization algorithm. Particle Swarm Optimization has the ability to produce better results than SA and ABC. PSO has been proved as an evolutionary computation technique. The algorithm proposed in this article may be designed to more parts with various operation sequences and more number of machines. The proposed method is rightly designed for high dimension problems. This technique gives best arrangement of production equipments in less time. This article concluded that the PSO is a better non-traditional optimization algorithm recommended to design and optimization of fixed area loop layout problem than SA and ABC. Also PSO is the suitable technique for solving the layout problems in less computation time. This proposed technique is simple and robust. It requires less number of coding lines and a few parameters.

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