Optimization of Facility Layout Problem of an Automotive Company using Simulated Annealing: A Case Study

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***Abstract*--In this paper a solution to the facility layout problem is presented. It is based on Simulated Annealing (SA), a recent and meta-heuristic approach to solve NP hard combinatorial optimization problems (like FLP).Increased competition globally in manufacturing industries and increases their focus towards the reducing manufacturing cost so an efficient facility layout required. Facility layout directly affects the productivity of industries as a result, there are need for various procedure and method for solving the facility layout problems. In manufacturing industries, the material handling cost function includes the transporting work in process, finished parts, tool and raw material between the facilities, the distance travelled by personnel or material handling between the facilities to be minimized. Simulated annealing (SA), a meta-heuristic technique is employed to solve a facility layout problem modeled as Quadratic Assignment Problem (QAP). In this paper work problem is taken from an automotive industry. The main objective is to find the best possible arrangement of all the facilities on the layout so as to minimize the total material handling cost of the company while satisfying all the constraints and keeping material flow smooth.**

Keywords: Simulated annealing (SA); Facility layout problem (FLP); Optimization.

I. INTRODUCTION

Facility layout problem is concern with is to find an optimal relative location of facilities on planar site (kouvelis et al.), in general terms smooth way to access the facilities. As defined in the literature the main objective of the facility layout problem is to minimize the total material handling cost (MHC). It estimated that 20-50% of operating cost in manufacturing industries are related to material handling and layout planning (Tompkins et al.). The main concern with the plant facility layout planning is to reduce the cost of materials handling as poor materials handling can generate business problems. To stay competitive in today's market a company must reduce costs by planning for the future. Material handling cost is an indirect cost and every company wants to reduce this indirect cost and it constitutes a major part of indirect costs in a facility. Therefore even small improvements in material handling costs makes a large reduction in total indirect costs. The cost of material flow is a function of the distance the material is moved between divisions called departments in a manufacturing facility.

II. LITERATURE REVIEW

The aim of the literature review is to expose the various aspects and dimensions over which facility layout problems are disseminated. We carried out the literature review to know that how facility layout (design) problems are formulated and what are the various solution approaches. As we are using simulated Annealing (SA) technique for solution of our problem so review is also carried out to know about the simulated Annealing (SA) algorithm, its application over facility layout problems and the efficacy of this method compared to other meta-heuristics in finding out an optimum solution.

- Matai et al. (2013), this paper, they presents a modified simulated annealing (SA) based approach to solve multi objective facility layout problem. It can incorporate more than two objectives that may be qualitative or quantitative in nature. Computational results show superiority of the proposed modified SA based approach for multi objective facility layout problem over past approaches available in literature.
- Matai et al. (2012), In this paper, they presented modified simulated annealing approach to solve the multi objective facility layout problem. It can incorporate more than two objectives which can be quantitative or qualitative in nature. Computation result for proposed simulated annealing approach show the better result to solve the multi objective facility layout problem.
- Lin lin And Chen fei (2012), this paper explained the basic principle of simulated annealing (SA) algorithm which was applied to solve the function optimization problem and algorithm realization process by using MATLAB. Through the improvement algorithm results show that the method is able to function for global optimization effectively. Improved simulated annealing (SA) algorithm not only can deepen the understanding of simulated annealing (SA) but also can achieve the purpose of design intelligent system.
- Matai et al. (2010), In this paper, they classified all the facility layout (design) problems on the

basis of various factors affecting the layout. Various solution approaches are described for solving the FLP's and are compared on the basis of their efficacy to find the best possible solution and time taken to finish the iterations to do this..

- McKendall and Shang (2006), This paper gave the procedure to deal with the solution of dynamic facility layout (design) problems (DFLP) using two different approaches of Simulated Annealing (SA). First approach considers the direct application of Simulated Annealing (SA) meta-heuristic for solving dynamic facility layout problem (DFLP). The second one is the improved one of the first approach. The whole procedure remains same with addition of look-ahead and look-back strategy. This data is taken from the literature for the experiment work to check the performance of these two approaches. The interpreted results show that multi dynamic facility layout problem (DFLP) can be dealt effectively by the proposed heuristics.
- Chwif et al. (1998), this paper gave the simulated Annealing (SA) algorithm for solution of facility layout (design) problem in a continual plane using simulated annealing (SA). And also present simulated annealing for general facility layout problem considering facilities area, shapes, orientation or in machine layout considering machine pick up and drop off point. They also discussed on problem formulation, formulation of objective function and proposed a simulated annealing (SA) algorithm based on Monte Carlo simulation allowing to solve the combinatorial optimization of facility layout problem (FLP) having different shape and size fixed facilities. The main problem faced by proposed Simulated annealing (SA) based algorithm to avoid overlapping with occupied space ratio above 75%. Although SA based algorithm is reasonable computationally and it shows good results.
- Connolly (1997), This paper discussed on the use of simulated annealing (SA) applied to the quadratic assignment problem (i.e. the assignment of inter-communicating objects to locations to minimize the total material handling cost between facilities). The result is a much-improved annealing scheme for this problem which performs well on a range of examples, finding improved solutions for several of the largest problems available in the literature and requiring only modest amounts of computational effort.

III. IDENTIFICATION & FORMULATION OF FACILITY LAYOUT PROBLEM

Facility layout problem (FLP) is a well-known problem and the finding location of facilities is a general problem encountered in manufacturing, service sector and many others. Formulation of FLP is done as Quadratic assignment problem (QAP) and QAP is NP-hard type which needs so much computation time even for a small size problem. Computational requirement grows exponentially as the size (number of facilities) of the problem increases.

Traditionally the facility layout problem modelled as Quadratic Assignment Problem (QAP) was proposed by Koopmans and Beckaman for the first time. The QAP has applied to wide range of application such as urban planning, control panel layout, facility layout design etc. The QAP is a special case of facility layout problem that all facility have equal areas and that all location. The name was so given because the objective function is a second degree function of variables and constraints are linear function of variables.

A. *Problem Identification*

Due to improper facility layout of the ABC Pvt. Ltd. company is facing the problem of high material handling cost, complex flow of materials. Due to improper arrangement of facilities the material has to travel unnecessary distance from starting to finish with in the plant. This increases the material handling cost. It also complicates the material flows. Facilities are not arranged in close affinity according to the process flows of the parts. Company has 9 no. of facilities from raw material to dispatch of finished parts. Facilities are located in such a way in plant so as to increases the center to center distance between facilities having material flow. Due to unnecessary distance travelled makes total material handling cost high and hence final cost of product. After consulting design and development head some of objectives given are to design a proper facility layout design which makes the flow of material smooth within plant. The following figure 3.1 and 3.2 represents the current layout of the company and current material flow in the plant.

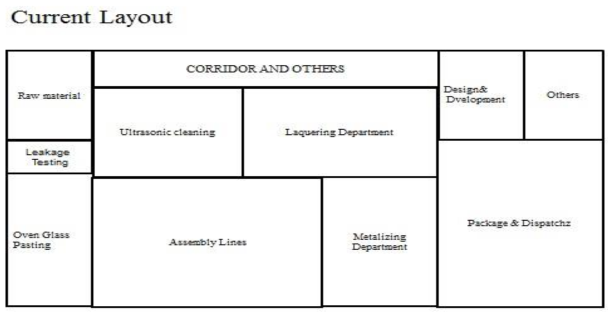

Fig. 1 Current layout

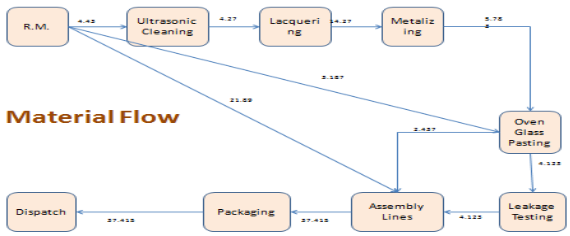

Fig. 2 Material flow diagram between various facilities

TABLE 1

CENTROIDS OF VARIOUS FACILITIES IN EXISTING LAYOUT

Sr. No.	**Name of facility**	**Co ordinate X**	**Co ordinate Y**
1	Raw Material	2.25	14.1
2	Ultrasonic cleaning	8.4	11.7
3	Lacquering department	15.3	11.7
4	Metalizing department	19.5	4.35
5	Oven glass for pasting	2.25	4.45
6	Ultrasonic welding & leakage test	2.25	10
7	Assembly department	10.5	4.35
8	Packing & dispatch	27	6
9	Design & development deptt.	20.55	15

B. Assumptions

To develop the mathematical model and to solve the facility layout problem some assumptions are taken as:

- All facilities are square or rectangular in shape with flexible dimensions and we assume all the facilities as square taking aspect ratio of length to width equal to one for using in Simulated Annealing (SA).
- The rectilinear distance between two facilities is calculated with respect to their centers.
- Only one location is assigned to a facility and only single facility can be assigned to a particular location.
- There should be no overlapping between the facilities.
- Flow data between all facilities is known.
- Each facility area remains unchanged.
- Aspect ratio value for all facility is known.
- Problem is formulated as single objective and single period problem facility layout problem.

C. Mathematical Modeling of the Facility Layout Problem

Facility layout problem mathematical modeled as:

- Problem formulation i.e. objective function that we have to optimize.
- Geometric constraints which need to satisfy
- Decision variable which need to determine.
- Solving Facility layout problem using Simulated Annealing (SA) with MATLAB coding.

The definition of decision variables is first important part towards the development of the mathematical model. Once the variable defined the construction of objective function and constraints is an easy task.

D. Center to Center Distance between Facilities

Here we have calculated the travel distance using rectilinear distance method. The formula used for this is given below

$D_{ij} = | x_i - x_j | + | y_i - y_j |$

TABLE 2

DISTANCE MATRIX

	Facilities *(i-j)*	**Centroidal Distance between facilities (m)**
1	1-2	8.55
2	1-5	9.65
3	1-7	18
4	2-3	6.9
5	3-4	11.55
6	4-5	17.35
7	5-6	5.55
8	5-7	8.35
9	6-7	13.9
10	7-8	18.15

TABLE 3

WEIGHT FLOW PER MONTH IN TONE AND DISTANCE BETWEEN FACILITIES

Facilities *(i-j)*	**Weight of Material Flow/month (tonne)**	**Centroidal Distance between facilities (m)**
1-2	4.43	8.55
1-5	3.187	9.65
1-7	21.89	18
2-3	4.27	6.9
3-4	4.27	11.55
4-5	5.783	17.35
5-6	4.123	5.55
5-7	2.437	8.35
6-7	4.123	13.9
7-8	37.415	18.15

TABLE 4

ASPECT RATIOS (MIN AND MAX) FOR EACH FACILITY

Facility No.	Min Aspect Ratio (a_{il})	Max Aspect Ratio(a_{iu})
1	0.1	6.5
2	0.15	7.5
3	0.3	2.6
4	0.5	1.8
5	0.5	1
6	0.15	2.5
7	0.3	1.8
8	0.5	1.5
9	0.5	1

E. Objective function and constraints

1) Objective Function:

$$\min Z = \sum_{i=1}^{m}\sum_{j=1}^{m} F_{ij}.D_{ij}.C_{ij}$$

Where

m = **9** = no. of facilities between which material moves or flow takes place

F_{ij} = Weight(volume) of flow between facilities i and j, measured as moves/frequency/weight per unit time and per unit distance or may be volume or weight of flow per unit time and per unit distance.

D_{ij} = Rectilinear distance of material flow between facilities i and j in meters.

C_{ij} = Rs. 25.89/tonne/m = cost/move among activities i and j per unit distance or we can say unit material handling cost

2) Constraints:

$D_{ij} = | x_i - x_j | + | y_i – y_j |$

Overlap Check

$(l_i + l_j)/2 - | x_i - x_j | \leq 0$

or

$(b_i + b_j)/2 - | y_i – y_j | \leq 0$

(l = b as facilities are taken as square)

$l_i , l_j , x_i , x_j , b_i , b_j , y_i , y_j \geq 0$

i = 1, 2, 3 ………….. n

j = 1, 2, 3 ………….. n

$i \neq j$

F. Minimum Safe Distance between Facilities to avoid Overlapping

Second and third constraints are introduced to avoid overlapping of facilities. One is to avoid interference along x-axis and another along y-axis. Figure 5.4 shows the minimum distance calculation to avoid interference.

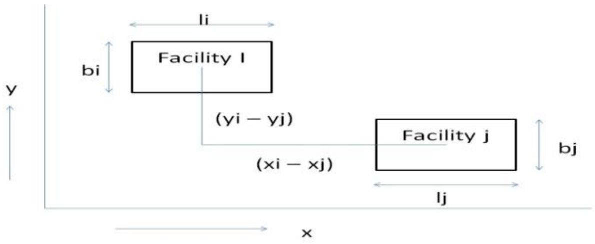

Fig. 3 the minimum distance calculation to avoid interference

IV. SIMULATED ANNEALING (SA) FOR FLP

A. Simulated Annealing

SA is a stochastic approach for solving combinatorial optimization problems, in which the basic idea comes from the annealing process of solids. In this process, a solid is heated until it melts, and then the temperature of the solid is slowly decreased (according to an annealing schedule) until the solid reaches the lowest energy state or the ground state. If the initial temperature is not high enough or if the temperature is decreased rapidly, the solid at the ground state will have many defects or imperfections. (Kirkpatrick et al.) were the first to use simulated annealing(SA) to solve a combinatorial optimization problem.

Before the development of meta-heuristics such as SA, tabu search, and genetic algorithms, many local search techniques (e.g., add/drop and exchange heuristics) were used to solve large combinatorial optimization problems. These heuristics, more specifically, the random descent pair-wise exchange heuristic, starts with an initial solution and move to r generate a neighboring solution (i.e., a solution slightly different from the initial solution) randomly. The cost of the neighboring solution is obtained and compared to the cost of the initial solution. If the cost of the neighboring solution is better (less than the cost of the initial solution), this solution becomes the best solution, and it is used as the starting solution at the next iteration. Otherwise, the initial solution is used as the starting solution at the next iteration. This process continues until a stopping criterion is reached. Often times this type of heuristic performs poorly (i.e., converges to a poor local optimum). To overcome this drawback, one technique that was considered was to apply the local search technique with multiple initial solutions. Although the probability of obtaining better local optimum increased, this technique was computationally costly but performed only slightly better. However, strategies, which use a local search technique that allowed accepting non-improving neighboring solutions, were considered and performed well. This is the idea behind the SA heuristic and other meta-heuristics. In other words, the idea of annealing is used to accept non-improving moves (or neighboring solutions) to avoid getting trapped at a poor local optimum. In SA, the probability of accepting non-improving moves initially is high, but as the search proceeds (and the temperature is reduced), the probability of accepting non-improving moves reduces.

B. Parameters:

The most important parameters of the simulated annealing (SA) Meta heuristic are the probability of acceptance and the annealing schedule.

C. Annealing Schedule:

The annealing schedule, also called the cooling schedule is the parameter settings for the SA heuristic, which is used to reduce the current temperature.

1) *Temperature function:* The current temperature is determined by the following equation:

$$T_c = T_0 \alpha^{r-1}, \quad r = 1, 2, \ldots, R,$$

Where T_0 is the initial temperature, α is called the cooling ratio and is usually set at 0.90, and R − 1 is the number of temperature reductions.

2) *Epoch length:* Before reducing the temperature, a number of accepted pair-wise exchanges need to be performed in order to ensure that the system is at a steady state. However, when the temperature is low, a large number of attempted pair-wise exchanges may be performed, since only a few pair-wise exchanges may be accepted. Therefore, the temperature should be reduced after a certain number of attempted exchanges (A) known as epoch length.

D. Probability of Acceptance

The probability of acceptance is defined as the probability of accepting a non-improving solution as the current solution. This is determined based on the following probability:

$$P(\Delta TC) = \exp(-\Delta TC / T_c),$$

Where T_c is the current temperature and ΔTC represents the change in total cost (i.e., the cost of the neighboring solution minus the cost of the current solution).

ΔTC = f (y ') − f (y)

If x is a randomly generated number between 0 and 1, and

x < P (ΔTC),

Then accept the non-improving neighboring solution y ' as the current solution (i.e., set y = y '). Otherwise reject the non-improving solution, and keep the current solution y. Initially, the probability of accepting a non-improving solution is higher, and this should be considered when determining the initial temperature. However, as the temperature is reduced, the probability of

.Simulated Annealing (SA) Algorithm

A straightforward simulated annealing Meta heuristic for the facility layout is given below.

Step 1: Input Data

The flow matrix.

Distance matrix. and

Unit material handling costs between each pair of facilities are given as input data.

Step 2: Define the SA parameters:

T_0 is the initial temperature, α is the cooling ratio, A the attempted number of moves at each temperature and T_{min} the minimum allowable temperature.

Step 3: Initialize the temperature change counter: r = 1.

Step 4: (a) Generate an initial solution y_0 and assign it to the current solution (i.e., set $y = y_0$).

(b) Obtain the cost of the current solution, f (y).

(c) Set the following parameters: Best-sol = y and Best-cost = f (y).

Step 5: Initialize counter for the number of attempted moves at each temperature: i = 0, and set the current temperature according to the annealing schedule, $T_c = T_0 \alpha^{r-1}$. If $T_c < T_{min}$, then explore the entire neighborhood of the Best-sol (i.e., use the steepest-descent pair-wise exchange heuristic), and return Best-sol and Best-cost.

Step 6: (a) Perform an iteration of the random descent pair-wise exchange heuristic. In other words, randomly select a period t, and then randomly select two departments' u and v in period t. Exchange the locations of departments' u and v in period t, and denote the neighboring solution as y '. Also, update i = i + 1.

(b) Calculate the change in total cost, ΔTC = f (y ') − f (y).

Step 7: If (ΔTC < 0) accept this solution

Or

If ΔTC > 0 Then

and x = random (0, 1) < P (ΔTC) = exp (−ΔTC/Tc)

Then set y = y ' and if Best-cost>f(y), then Best-cost = f (y) and Best-sol = y.

Step 8: If i = A, then update r = r + 1, and go to Step 3. Else, go to Step 4.

Initially, the heuristic parameters α, A, and T_{min} are defined and obtained experimentally. In other words, α and A were obtained using experimental techniques and T_{min} is set to value 0.01 (i.e., $T_{min} = 0.01$).

Furthermore the initial temperature is determined such that the probability of accepting a neighboring solution with a cost of 10% above the cost of the initial solution is 0.25, which gives the equation

$$T_0 = -\Delta TC / \ln (P(\Delta TC)) = -0.10 f(y_0) / \ln(0.25)$$

Since P (ΔTC) = exp (−ΔTC / T_c) and T_c = T_0 for r =1.

In Step 2, y_0 = [ax_0 (1), ax_0 (2) . . . ax_0 (T)], is generated and is assigned to the current solution or layout plan, y. The n-component vector ax_0 (t) in the initial solution vector represents the initial layout for period t, where t = 1, 2 . . . T. Also, ax_0 (t) = [x_0(1), x_0(2) . . . x_0(N)] such that the element x_0 (i) in the initial assignment vector represents the location of department i, where i =1, 2 . . . N.

In Steps 2 and 3, the heuristic parameters and counters are initialized. Also, if the stopping criterion as been reached (i.e., Tc < Tmin = 0.01), in Step 3, the heuristic is terminated after the entire neighborhood of the Best-sol is explored, and the best solution obtained is given. Otherwise in Step 4, the random descent pair-wise exchange heuristic is used to obtain a neighboring solution y ', and the change in total cost ΔTC is obtained. Also, the counter used to count the number of attempted pair-wise exchanges at the current temperature is updated. In Step 5, if ΔTC < 0, then the neighboring solution y ' is accepted as the current solution y since f (y ')< f(y). Also, the Best-cost and Best-sol is updated if necessary. If ΔTC > 0 (i.e., f (y ') > f(y)) and x < P (ΔTC), where x is a randomly generated number between 0 and 1, then y ' is accepted as the current solution (i.e., set y = y ') although y ' is worse than y. Otherwise, the current solution y does not change. In Step 6, for the current temperature, the number of attempted pair-wise exchanges is compared to A.

If less than, then the local search technique is implemented, in Step 4, and continues from there. Otherwise, the temperature is increased in Step 3. This process is repeated until the current temperature T_c drops below 0.01 (i.e., T_c < T_{min} = 0.01).

E. Flow chart of Simulated Annealing (SA) for FLP

The flow chart of the SA for facility layout problem is shown in the figure

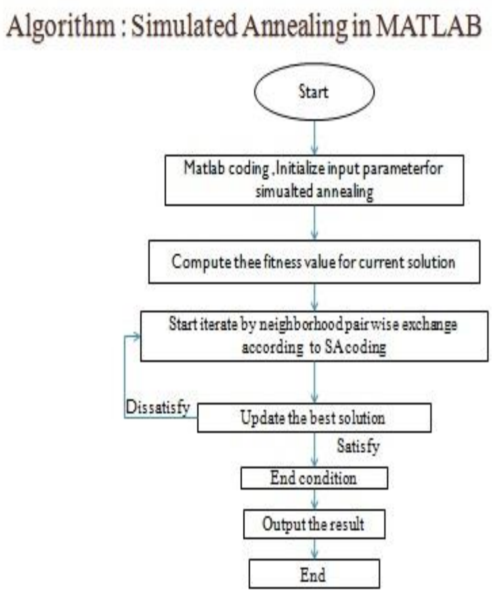

Fig 4. SA algorithm

V. RESULTS AND DISCUSSION

SA results

A. Optimization through Simulated annealing (SA)

The mathematical model for facility layout problem is to minimize the total distance between various facilties. We optimize the model with help of simulated annealing algorithm A programming code for Simulated annealing algorithm was written in MATLAB software. The latest version of MATLAB used for programming is R2010a.

Initial Temperature for SA T_o =1 Cooling ratio =.95 T_{min}=0.01

Input parameter

1. Distance matrix (D_{ij})

2. Flow matrix (F_{ij})

3. Unit material handling cost (C_{ij})

MATLAB version used for programming is R2010a.

shows the original co ordinates and optimized co ordinate obtained by the algorithm..

TABLE 5

COMPARISON OF ORIGINAL AND OPTIMIZED CO ORDINATES

Facility No.	Original Coordinates	Optimized Coordinates
1	2.25,14.10	13.4,12.9
2	8.4,11.70	13.4,18.65
3	15.3,4.35	20.45,20.2
4	19.5,4.35	6.65,20.2
5	2.25,4.45	7.1,13.45
6	2.25,10.00	6.75,5.2
7	10.5,4.35	13.4,5.2
8	27.0,6.0	23.7,5.2
9	20.55,15.0	2.6,5.2

By running simulated annealing (SA) MATLAB program, we get the centroids of each facility of the layout in the result. By using these centroids we can draw the optimized layout. Optimized layout obtained is shown in the fig

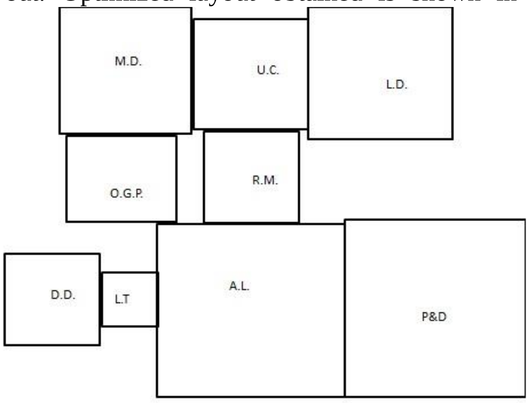

Fig 5. optimized layout

B. Proposed Layout

The optimized facility layout obtained by running simulated annealing (SA) MATLAB program is adjusted according to the aspect ratios of various facility within layout and new modified layout is prepared. Table 6.2 shows the existing and optimized co ordinates after adjustment.. Table 1.4 shows the existing coordinates and optimized coordinates after adjustment.

TABLE 6.

COMPARISON OF ORIGINAL AND PROPOSED CO ORDINATES

Facility No.	**Original Coordinates**	**Optimized Coordinates**
1	2.25,14.10	12.675,9.034
2	8.4,11.70	14.25,11.284
3	15.3,4.35	15.1,15.25
4	19.5,4.35	4.75,15.25
5	2.25,4.45	3.075,9.25
6	2.25,10.00	5.325,3
7	10.5,4.35	13.635,4
8	27.0,6.0	25.57,4.24
9	20.55,15.0	2.25,3

After modification the shapes of the facilities change and hence the coordinates, which alter the distance between the facilities. The figure 5.2 shows the proposed layout.

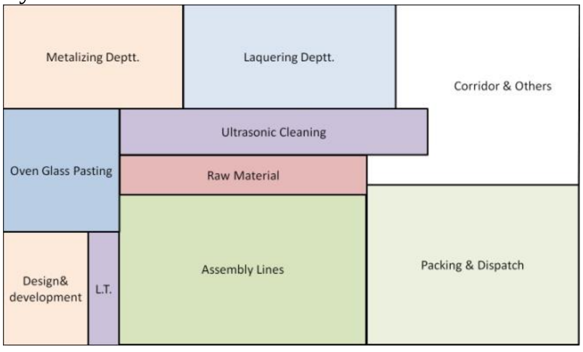

Fig. 6 proposed layout

C. Distance optimization

After the reshaping the facilities new dimensions and centroids are available. Now we can calculate the facility to facility distance. The main aim of minimizing the material handling cost depends on minimizing the distance between the facilities having material flows between them. The distance matrix obtained from the algorithm differs from the modified solution, because the reshaping changes the inter facility distance. We compare the distance matrix obtained from modified solution with the existing one. The table 1.5 shows the earlier (existing) & proposed (optimized) facility to facility distance values (in meters) for all the facility pairs between which the material flow takes place.

TABLE 7

COMPARISON OF ORIGINAL AND OPTIMIZED DISTANCE

Facilities *(i-j)*	**Existing distance** (m)	**Optimized distance** (m)
1-2	8.55	3.825
1-5	9.65	9.816
1-7	18	5.994
2-3	6.9	4.816
3-4	11.55	10.35
4-5	17.35	7.675
5-6	5.55	8.5
5-7	8.35	15.81
6-7	13.9	9.31
7-8	18.15	12.175
TOTAL	117.95	88.271

Figure 7 shows the statistical comparison between the existing (old) and proposed (optimized) distances between various facilities.

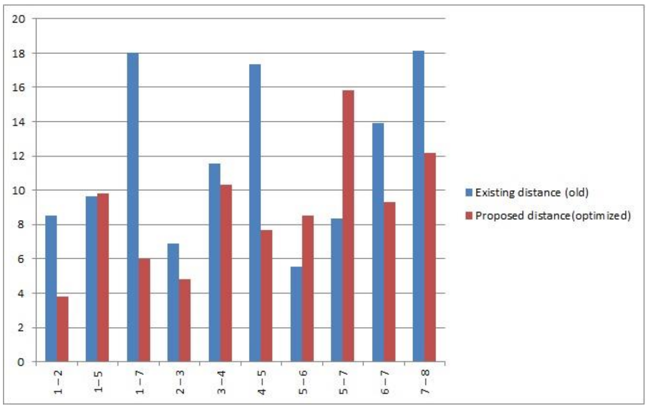

Fig. 7 Statistical comparisons of the existing and the proposed (optimized) distances

The red blocks represents the proposed (optimized) facility to facility distance value and blue blocks represents the existing (old) facility to facility distance value. Summing up all proposed distances we get total 88.271meters. So total 29.679 (117.95-88.271) meters. These proposed distances contribute towards the minimization of material handling cost (MHC).

VI. CONCLUSIONS

This paper conclude that Facility layout directly affects the productivity of the firm, so it is very important solve it carefully. Facility layout problem can be defined as optimization problem and a mathematical model way to solve. The main objective of facility layout problem is to minimize the total material handling cost by minimizing the total distance travel by material within firm.

The problem taken from an automotive industry is solved using simulated annealing (SA) algorithm by coding in MATLAB software. MATLAB program is run for simulated annealing algorithm by defining input parameters. Solution obtained by running program is obtained in the form of centroids of square as we modelled our problem by taking square facilities. The solution obtained is readjusted using aspect ratios.

REFERENCES

[1] Matai R. et al., "Modified simulated annealing based approach for multi objective facility layout problem", International journal of production research, vol.51, issue no.51, pages 4273-4288, 2013.

[2] Sharma P. et al., "A review of meta heuristic approaches to solve facility layout problem", International journal of emerging research in management and technology, vol.2, issue no.10, 2013.

[3] Matai et al., "A new heuristic approach to solve the facility layout problem", International journal of advanced operations management, vol.5, pages.137-158, 2013.

[4] Reddy S.N. et al.. "Optimization of multi objective facility layout using non traditional optimization technique". International journal of engineering science and technology, vol.4 Issue no.2, 2012.

[5] Matai et al., "Solving multi objective facility problem: modified simulated annealing approach", European journal of management, vol.12, issue no.2, 2012.

[6] Kundu A. and Dan P.K., "Met heuristic in facility layout problems: current trend and future direction" Int. J. Industrial and Systems Engineering, Vol. 10, No. 2, 2012.

[7] Lin Lin and Fei Chen, "The simulated annealing algorithm implemented by the MATLAB", International journal of computer science, vol.9, issue no.6, 2012.

[8] Matai R. et al., "Facility layout problem: A state of the art review", XIMB journal of management, vol. 7, issue no. 2, pages 81-106, 2010.

[9] Keivani A. et al., "A simulated annealing for multi floor facility layout problem", Proceedings of the World Congress on Engineering and Computer Science, vol.2 , October 20-22, 2010.

[10] Dirira A. et al.. "Facility layout problem: A Survey", Annual review in control 31, www.elsevier.com pages 255-267, 2007.

[11] Singh S.P. and Sharma R.R.K., "A review of different approaches to facility layout problem", Int. journal of advance manufacturing technology, vol.30, pages.425-433, 2006.

[12] McKendall AR and Shang J., "Simulated annealing heuristics for the dynamic facility layout problem", Computers & Operations. Research, vol. 33, pages 2431-2444, 2006.

[13] Suman B. and Kumar P., "A survey of simulated annealing as a tool for single and multi objective optimization", Journal of operation research society vol.57, pages. 1143-1160, 2006.

[14] Chwif L. et al., "A solution to the facility layout problem using simulated annealing," Computers in Industry, vol. 36, pages 125-132, 1998.

[15] Meller R.D. and Bozer, Y.A., "A new simulated annealing algorithm for facility layout problem", International journal of production research, vol.34, issue no.6, pages.1675-1692, 1996.

[16] Tain Peng. et al., "Simulated annealing for the quadratic assignment problem : a further study", in proceedings of 18th International conference on computers and industrial engineering, vol.31, pages. 925-928, issue 3-4, December 1996.

[17] Heragu S.S., "Recent model and technique for solving the layout problem", European journal of operational research, vol.57, pages. 136-144, 1992.

[18] Heragu S.S. and Alfa A.S., "Experimental analysis of simulated annealing based algorithms for the layout problem", European journal of operational research, vol.57, pages.190-202, 1992.

[19] Connolly D.T., " An improved annealing scheme for the QAP", European journal of operation research,vol.46, issue no.1, pages 93-100, 1990.

[20] Kusiak A. and Heragu S.S., "The facility layout problem", European journal of operational research,vol.29, pages. 229-251, 1987.

[21] Wilhelm M.R. and Ward T.L., "Solving quadratic assignment problems by simulated annealing", IIE Transactions, vol.19(1), pages. 107-119, 1987.

[22] Arikaran P et al., "Analysis of Unequal Areas Facility Layout Problems", International Journal of Engineering (IJE), vol.4, issue no.1, pages 44-51, 2010.

[23] Azadivar F. and Wang J., "Facility layout optimization using simulation and genetic algorithms", International journal of production research, vpl.38, issue no.17, pages. 4369-4383, 2000.

[24] Alvarenga A.G.D. et al., "Meta hueristic method for class of the facility layout problem", Journal of intelligent manufacturing-11, pages.421-430, 2000.

[25] Tompkins J.A. et al., "Facilities planning", 3rd edition, Wiley, New York, 2003.

[26] Kirpatrick S. et al., "Optimization by simulated annealing", Science 220, pages.671-680, 1983.

[27] Kouvelis P. et al., "Simulated annealing for machine layout problems in the presence of zoning constraints", European journal of operational research, vol.52 (2), pages. 203-223, 1992.

[28] Suresh G. and Sahu S., " Multiobjective facility layout using simulated annealing", Internation journal of production economics, vol.32, issue no. 3, pages. 239-254, 1993.

[29] Heragu S.S. and Alfa A.S., "A simulated annealing based approach to solve the facility layout problem", in proceedings of the Fourth Advanced Technology Conference, Washington DC, Pages.489-499, 1990.

[30] Heragu S.S. and Kusiak A.S., " Efficient models for the facility layout problem", European journal of operational research, vol.53, pages. 1-13, 1991.

[31] Koopmans T.C. and Beckmann M., "Assignment problems and the location of economic activities", Econometrica, vol.25, pages. 53-76, 1957.