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An Approach For Layout Improvement Of Production Floor Based On Material Handling Cost

Mr. Subrata Talapatra, Md. Fashiar Rahman, Md. Shah Ali Mollah, Nirupom Paul
Department of Industrial Engineering & Management, KUET, Khulna, 9203, Bangladesh
Sub_ksy@yahoo.com

Abstract— ***As material handling is the fundamental activities in manufacturing system, it is necessary to keep the handling cost within the minimum limit. Though there are many available algorithms for material handling, here a completely new algorithm has been developed to improve layout aiming to optimize the material handling cost and empirically tested for the better understanding and comparison with Genetic Algorithm.***

Keywords—Material handling, Genetic Algorithm, layout, Cost optimization.

I. Introduction

The industries are experiencing a very competitive era like many others, thus striving hard to find methods to reduce manufacturing costs, improve quality etc. As part of a productivity improvement program in a manufacturing company we conducted a project to optimize the layout design of the production line at the shop floor of this company aiming at overcoming the current problems attributed to the inefficient layout. It was decided to apply a number of layout modelling techniques to generate a near optimal layout based on formal methods that are rarely used in practice. The modelling techniques used are Graph Theory, Bloc Plan, CRAFT, Optimum Sequence and Genetic Algorithm. These layouts were then evaluated and compared using three criteria namely Total Area, Flow * Distance and the Adjacency Percentage. Total Area refers to the area occupied by the production line for each model developed. Flow * Distance calculates the sum of products of the flow and the distance between every two facilities. Adjacency Percentage calculates the percentage of the facilities that meet the requirement of being adjacent. Selection of the best layout was also done formally using multi-criteria decision making approach AHP using Expert Choice software [i]. The best layout was compared with the existing layout to demonstrate improvements gained by formal approaches to layout design.

Material handling equipment is, like the name implies, the equipment needed to handle the material at issue. Tompkins et al. classifies the material handling equipment into four different categories [ii]:

I. Containers and unitizing equipment.
II. Material transport equipment.
III. Storage and retrieval equipment.
IV. Automatic data collection and communication equipment

The material handling equation system equation (figure 1) is a tool that can assist the work of developing alternative material handling system design. The question what deals with what type of materials that is to be moved. Where and when deals with time and place. How and when are concerned the material handling methods. Together these questions give the material handling system equation: Materials + Moves + Methods = Recommended system. The important thing is that for each of these questions one asks oneself why? Why is this amount stored? Why is the material stored in this location? Why is the material moved in this way? Etc [ii].

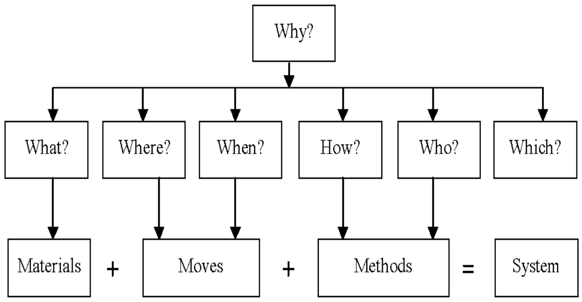

Figure 1 Material handling system equation

Material handling models are categorized depending on their nature, assumptions and objectives. The first generic Systematic Layout Planning approach, developed by Muther [iii], is still a useful scheme specially if supported by other approaches and assisted by computer. Construction approaches, Hassan and Hogg (1991) for example, build a layout from scratch while Improvement Methods. Bozer, Meller and Erlebacher (1994) for example, attempt to modify an existing layout for better results. Optimizing methods and also heuristics for layout by is well documented by Heragu (2007). De-Alvarenga and Gomes (2000) discuss a meta-heuristic approach as a way to overcome the NP hard nature of optimal models. The various modelling techniques used in this work are Graph Theory, CRAFT, Optimum Sequence, BLOCPLAN and Genetic Algorithm [iv].

II. Methodology

Development of new model

This model calculates material handling cost of all of the possible models formed by interchanging machines or displacing machines in different possible spaces. The other models try to minimize/optimize cost as possible but never guarantee about cent percent optimize or minimize the cost. On the other hand this developed model minimizes material handling cost cent percent from which it is not possible to minimize.

In this model the following steps are followed

1. Takes any arbitrary or existing layout
2. Prepares all of the possible layouts
3. Determines the cost for each layout

4. Takes the first cost and compares with cost of other layouts to determine if there is any layout that requires less cost
5. If a layout is found that promises less cost than the former taken for comparison, taken and is compared with the rests layouts to determine if there is any layout that requires less cost
6. Steps 4 and 5 are repeated again and again until reaching the last layout prepared and
7. The last layout that found after comparing are the result of this model

When there are many machines and/or spaces in which machines can be placed the above calculation is hard and time consuming. It may take more than 0.365 million of calculations for only having 6 spaces and4 machines. So it will need million billion calculations when spaces and machines will be increased. So making mistake is very possible and may take several months even several years when doing calculation manually. So it is necessary to do something that will do this calculation with tolerable time. To do this an algorithm has been developed that can do this work with tolerable time with the help of computer.

This algorithm can be said in the steps:

I. Prepare all of the layout as possible and guess the first as **A** and the second as **B**
II. Determine the cost of all layouts found in the first step
III. Compare cost of **A** with the cost of **B**
IV. If the cost of **B** is not less than the cost of **A** and there if there is more layer after **B**, put cost of **B** as cost of **A** and cost of next of **B** as cost of **B** and go to steps iii. But if there is no more layer after **B,** Take layout A as final cost minimized layout
V. Check if the cost of **B** is less than the cost of **A** and there is there is more layer after **B**, put cost of **B** as cost of **A** and cost of next of **B** as cost of **B** and go to steps iii. But if there is no more layer after **B,** Take layout **B** as final cost minimized layout
VI. Then finish.

The algorithm is shown as a diagram below:

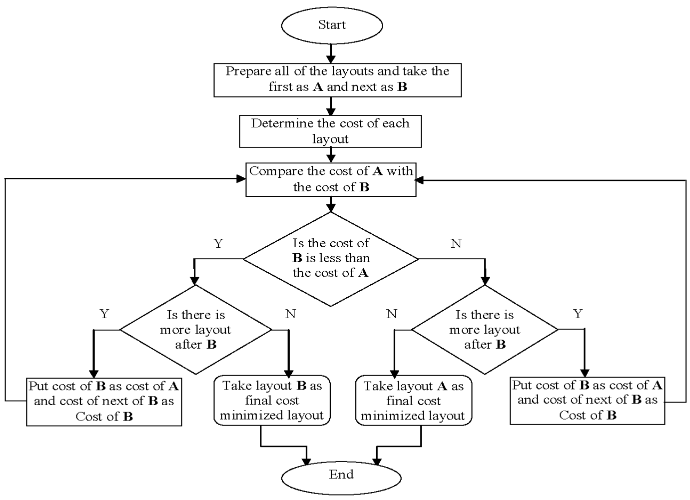

Figure 2 Algorithm for the developed layout design model

Necessary Inputs for this program

1. Number of spaces

Number of spaces indicates the number of possible places in which machines can be placed.

2. Number of machines and their positions

In this case total number of machines is to be given. After that it is necessary to initialize the position of each machine.

3. Stability of machine

In some case it may be necessary to make one or more machines to be stable in a fixed position. So it is necessary to tell the computer that machines should be stable in the specific place/position.

4. Material flow

It is necessary to mentioned how much material will be flowed from which machine to which machine.

5. Distance between locations

To calculate cost of material handling between two machines (i.e. locations) distance between two locations is needed to know. So distances between all of two locations are record in this input.

6. Costs

Cost includes both of the fixed and variable cost for material handling.

7. Type of combinations
   a. *All layout*
      If it is necessary to see all of the layouts; it doesn't depend on the cost.
   b. *Only the desired layout*
      This gives the target layout with minimum cost of material handling.

III. Application of new developed model

The following figure shows the original layout of Bangladesh Cable Shilpa Ltd., Khulna. Here the specific numbers (1, 2, 3, 4, 5, and 6) address the space locations. And the arrows show the flow direction of material handling between machines.

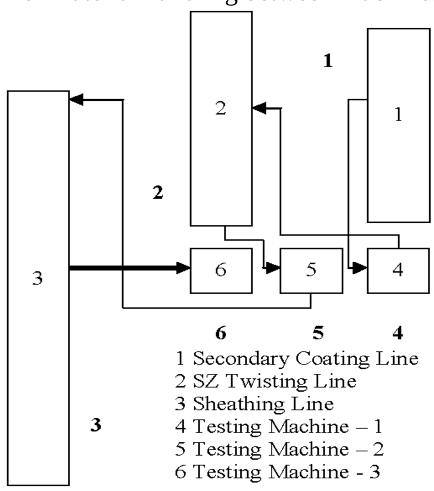

Figure 3 Existing Layout of BCSL

Input necessary for BCSL in this program

1. Number of spaces

The number of spaces in BCSL indicates is 6.

2. Number of machines and their positions

In BCSL total number of machines also 6 equal to space number.

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Table 1 Respective location of machine for initial layout

Position of machine	1	2	3	4	5	6
Machine number	1	2	3	4	5	6

3. Stability of machine
   There is no stability of machines in this case.
4. Material flow
   In machine shop there materials flow from one machine to another is shown in the following table
5. Distance between locations
   To calculate cost of material handling between two machines (i.e. locations) distance between two locations is needed to know. So distances between all of two locations are recorded in this input shown in the following table.

Table 2 distances between locations in metre (Li, Lj)

Li\Lj	1	2	3	4	5	6
1		2	8	62	63	64
2			6	6	5	4
3				36	35	34
4					2	6
5						1
6						

6. Costs
   BCSL follows fixed cost system.
   Cost of per unit material handling per unit of distance = 0.0206 BDT/kg. Of material/metre.
7. Type of combinations
   Only the desired layout is necessary.
   To get desired layout, only it is necessary when computer asks to press N for desired layout.

After giving all the data following output, as screenshot, is found.

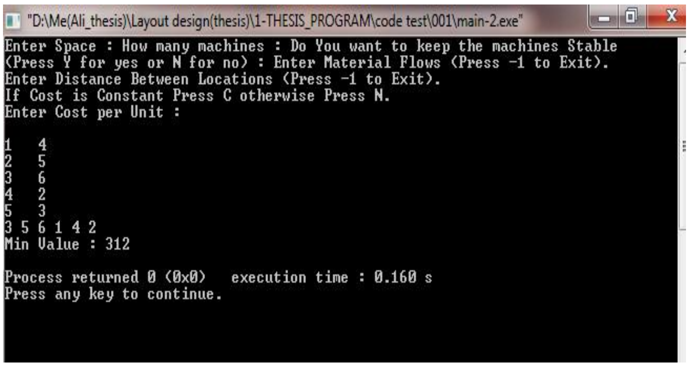

Figure 4 Screenshot of output for cost minimized layout

Table 3 Respective location of machine for developed layout

Position of machine	1	2	3	4	5	6
Machine number	3	5	6	1	4	2

The new rearranged layout according to the developed algorithm is shown below:

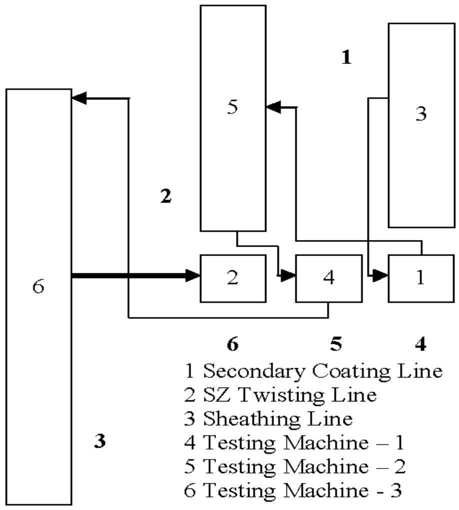

Figure 5 Developed layout of optical fibre section of BCSL

Cost calculation

Cost of material handling for layout,

$$C = \sum_{i=0}^{M} \sum_{j=1}^{M} Gij * Lij * Cij \qquad \text{.......................(1)}$$

Here, M= Total number of machines.
i, j= Machine number.
Gij=Amount of material flow from i th machine to j th machine.
Lij=Distance between the locations where i th machine to j th machine are located.

So, cost of mateial handling for initial layout,
$C_{initial}$ = (72*62 + 12*5 + 3*34 + 72*6 + 12*35) * 0.0206 TK.
= 112.847 TK.
and
cost of mateial handling for developed layout,
$C_{developed}$ = (72*62 + 12*4 + 3*35 + 72*6 + 12*34)*0.0206TK
= 112.414 TK
Above calculation is done for one cycle of production.
So the difference between initial and developed layout is,
= 112.847 TK. - 112.414 TK
= 0 .433 TK
Percent of cost decrease is = 0.433/112.847 * 100%
= 0.383 %
So it can easily be said that the initial layout can be changed a little as found from the application of developed model.

IV. Result and Discussion

For the better judgement of the new developed algorithm and its application it is necessary to compare the result with other conventional modelling of layout. As Genetic Algorithm is widely used for this purpose, the new developed result is showed in comparison with Genetic Algorithm.

Genetic algorithms (GAs) can be defined meta-heuristics based on the evolutionary process of natural systems [v]. Since their inception, they have been applied numerous optimization problems with highly acceptable results. GAs is new approach to solving complex problems such as determination facility layout. The GAs contain the elements of the methods of blind searching for the solution and of directed and stochastic searching and thus give compromise between the utilization and searching for solution. At the ginning, the search in the entire search space and afterwards, by means of crossover, they arch only in the surrounding of the promising solutions. So GAs employed random, yet reacted search for locating the globally optimal solution [vi]. The starting point in GA presented in this work was an initial population of solutions which as randomly generated.

The selection, mutation, operators were used for generation of solutions. A evaluates the designs and decides the survivors into the Selection is accomplished by from the last generation based on a fitness Mutation is the process changing one bit of information and it prevents GAs from stagnating the solution process. Responsible for introducing solutions by selecting two random and exchanging parts a parent selection procedure work operates as follows:

1. Generate initial population consisting of members using random number of Generator.
2. Place all population members in main database.
3. Calculate the fitness C (Eq. (1)) of all population members.
4. Chose the population member whose fitness has minimum value compared with fitness of the other population members as the first parent.
5. Place chosen population member in separate database.
6. Repeat procedure (1-5) once more to produce second parent chromosome.

Table 4 First population consisting of 5 members

Serial/Location	1	2	3	4	5	6
1	1	2	6	4	3	5
2	6	1	2	3	4	5
3	2	3	1	6	4	5
4	6	5	1	2	3	4
5	4	5	1	2	3	6

Cost calculation for first population,
For member 1 cost is = (72*63 + 12*4 + 3*35 + 72*6 +12*1)*.0206 TK = 104.257 TK
For member 2 cost is = (72*5 + 12*64 + 3*62 + 72*35 +12*6)*.0206 TK = 80.46 TK
For member 3 cost is = (72*35 + 12*64 + 3*6 + 72*63 +12*4)*.0206 TK = 164.017 TK
For member 4 cost is = (72*35 + 12*6 + 3*63 + 72*6 +12*5)*.0206 TK =***67.420*** TK
For member 5 cost is = (72*8 + 12*6 + 3*1 + 72*62 +12*5)*.0206 TK = 106.605 TK

Table 5 Second population consisting of 4 members

Serial/Location	1	2	3	4	5	6
1	5	1	4	6	2	3
2	6	5	4	1	2	3
3	1	2	3	4	6	5
4	5	2	3	1	4	6
5	1	2	3	5	4	6

Cost calculation for second population,
For member 1 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK =92.57 TK
For member 2 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK =125.41 TK
For member 3 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK = 112.414 TK
For member 5 cost is = (72* + 12* + 3* + 72* +12*)*.0206 TK = 113.412 TK

Now there is two parent chromosomes whose fitness are the best compared to the rest of the population. The probability that the fitness of one of two parents is total minimum of studied example is very small. The starting chromosome in new iteration isn't randomly generated. It is the chromosome obtained by crossover of two parents chromosomes discussed above. Consider a pair of parent chromosomes (P1, P2) shown below:

Table 6 Second population consisting of 4 members

P1	6	5	1	2	3	4
P2	5	1	4	6	2	3

The way of crossover implementing in this work was chose four central numbers of both parents i.e. (8,4,2,5) in P1 and (5,7,9,6)in P2, but we do not exchange it from P1 toP2 and vice versa (the procedure explained and used by Chan and Tansri [vii]; Mak,Wong and Chan [viii]). we only change their string in original chromosome of one parent in the way they are lined in the other. To be precisely, numbers 8,4,2,5 in P1 should be lined as 2, 5, 8,4 in P1, and numbers 5,7,9,6 in P2should be lined as 9,6,5,7 in P2. At this stage genes cannot be found to exist in more than one position in the resultant chromosomes. The structures of the resultant chromosomes then become :(after mutation)

Table 7 Second population consisting of 4 members

P1	6	5	1	2	3	4
P2	5	1	4	6	2	3

Cost after mutation:
For P1 cost C1= (72*62 + 12*4 + 3*8 + 72*6 +12*6)*.0206 TK =103.82 TK
For P2 cost C2= 72*34 + 12*2 + 3*36 + 72*5 +12*4)*.0206 TK =74.65 TK

Crossover

Table 8 Second population consisting of 4 members

P1	**3**	5	**6**	4	1	2
P2	5	2	**6**	**3**	1	4

Cost after cross over,
For P1 cost C1= (72*2 + 12*5 + 3*35 + 72*34 +12*8)*.0206 TK =58.77 TK
For P2 cost C2= (72*34 + 12*2 + 3*36 + 72*4 +12*8)*.0206 TK =**60.56**TK ***
Competitive cost analysis among existing layout, improved layout with developed algorithm and genetic algorithm:

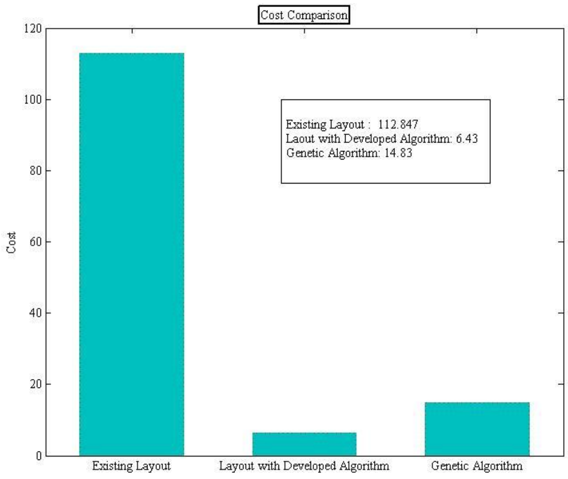

Figure 6 Competitive cost analysis

V. Conclusion

The main focus here is to prevent extra material handling cost in our industrial sector. Aiming to this, all the available methods had examined to optimize the material handling cost and finally a new algorithm has been proposed and the result has been shown by applying the algorithm with C++ programming. The effectiveness of the outcome has been depicted by comparing with Genetic Algorithm.

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