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FACILITY LAYOUT OF A MILK DAIRY-A CASE STUDY

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Abstract
In this article, we present a case study on the facility layout of a dairy products firm**.** We used the case data to develop a new layout with a flexible bay structure. The formation of flexible bays in the layout helps the proper design of the aisle structure in the layout. The new layout is developed by using the Simulated Annealing for Flexible Bay Structure (SA-FBS) solution approach of Hunagund et.al. (2021). Rearrangement cost for the newly generated layout is taken as 20% of the SA-FBS solution value. The total cost of the newly developed layout is computed by adding both the SA-FBS solution value (i.e., MHC) and the rearrangement cost. The material handling cost of the existing layout is computed by using the existing distance between facilities. Then the total cost of new the layout is compared with the existing layout's material handling cost. The layout obtained by using the SA-FBS approach to case data has not only given the lesser material handling cost but also provided a safer shop floor for the movement of men and materials.
Keywords: Case Study; Facility Layout Problem; Flexible Bay Structure; Simulated Annealing.

1. Introduction

The optimal placement of facilities on the plant floor area plays important role in reducing the operating cost of the company. Material handling cost (MHC) is a major factor considered in the optimal design of the facility layout of a firm. Hence most of the research works on facility layout design considers minimization of the material handling cost, with other sub-objectives. According to Tompkin et al [1], the material handling cost assumes about 20-50% of the total operating cost of the facility layout. Material handling cost is a non-value-added cost. Effective facilities planning can reduce these costs by at least 10% to 30% and thus increase productivity. Therefore the optimal design of the physical layout of the manufacturing system is one of the most important issues. Also, the flexible bay structure is one of the important facilities arrangement in the layout. The formation of flexible bays in the layout helps the proper design of aisle structure in the layout. The proper aisle structure helps in the easy and safe movement of material handling equipment, men, and materials.

The need for layout planning arises as a part of the design of new facilities as well as the redesign of existing facilities. The redesign of the layout becomes essential due to in-efficient operations (e.g., high cost, bottlenecks), accidents or safety hazards, changes in the design of products or services, introduction of new products or services, changes in methods, changes in the volume of output or a mix of outputs, and changes in environmental and other legal requirements.

Hence in the present work, initially, a case study is made in the milk and dairy products firm in Bangalore. Initially, the existing layout in the firm is analysed and the existing layout cost is computed from the data collected. Then a new layout is developed for the collected data by considering the Unequal Area Facility Layout Problem (UA-FLP) with Flexible Bay Structure (FBS) using Simulated Annealing for Flexible Bay Structure (SA-FBS) of Hunagund et.al [2]. Then a comparison between the existing layout and the newly generated layout is made. The rest of the paper is organized as follows: Section 2 gives the literature review; Section 3 gives the case description; Section 4 presentation of case data and methodology to develop new layout; Section 5 gives the methodology followed in developing a new layout and discussion of results; Section 6 presents the conclusions and future scope for further research.

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2. Literature Review

Koopmans and Beckmans [3] were the first to formulate the facility layout problem as a quadratic assignment problem (QAP), which assigns *n* departments to *n* locations while minimizing the material handling cost. However, QAP is known to be NP-complete, and no known method is capable of solving the problem with 15 or more facilities optimally in a reasonable amount of time. Hence many researchers use heuristic methods to solve the QAP [4-9]. In practical situations, facilities have usually different areas. Hence, recent works on facility layout design consider the unequal Area facilities. Unequal Area Facility Layout Problems (UA-FLPs) are generally represented on continuous space and are formulated as mixed integer programming problems [10-12], and are computationally more complex. For a comprehensive review of the existing methods for the facility layout problem, and discrete space and continuous space facility layout problems, see [6, 13, 14].

UA-FLPs represented on continuous space determines location coordinates of facilities and their sizes while designing the layout for a required objective. UA-FLPs represented on continuous space are solved either with an assumption of a larger floor area than the area required for all facilities [10, 11] or with the floor area equal to the sum of all facilities area Hence many researchers take the floor area equal to the sum of all facilities areas [2, 15-24]. In the former case, facilities get clustered towards the centre of the plant. This clustering of facilities at the centre of the plant area is overcome by arranging the facilities in Slicing Tree Structure (STS) [15-18] or in Flexible Bay Structure (FBS) [19-24].

In STS, the plant area is partitioned both in vertical and horizontal directions simultaneously whereas, in FBS, the plant area is portioned either in vertical or horizontal direction only, but not both. In FBS, the width of vertical or horizontal bays is flexible depending on the sum of facilities area within each bay, and also, the facilities are not allowed to span over multiple bays. Tate and Smith [25] first time represent the UA-FLP by a flexible bay structure (FBS) and use a Genetic Algorithm (GA) as the solution method. The FBS formulation is made a more Relaxed Flexible Bay Structure (RFBS) by allowing extra area or space within each bay [21, 22, 26]. UA-FLP with FBS representation is more constrained than STS due to the creation of bays. Hence, optimal UA-FLP designs based on the FBS are expected to have a higher material handling cost than the corresponding optimal designs based on STS. However, FBS can easily be adapted for creating the aisles in the detailed layout plan and this helps users to implement the layout plan easily on the shop floor. Hence in the present study, Flexible Bay Structure (FBS) is considered in generating the new layout for the case data.

3. Case Description

The firm under consideration is engaged in producing different types of dairy products. Its name is Bangalore Milk Union Limited (BAMUL). BAMUL was established in 1975 by keeping "AMUL" as its Role Model. At present, BAMUL has its operations in Bangalore Urban, Bangalore Rural, and Ramanagaram Districts Co-Operative Milk Producers Societies Union Ltd of Karnataka. It procures the milk from all these districts and sells it in Bruhath Bangalore Mahanagara Palika (BBMP) and its surrounding areas. The Bangalore Milk Union Ltd., (BAMUL) is a unit of Karnataka Cooperative Milk Producers Federation Limited (KMF) which is the Apex Body in Karnataka representing Dairy Farmer's Co-operatives. It is the second largest dairy co-operative amongst the dairy cooperatives in the country after AMUL of Gujarat state. The Brand "NANDINI" is the household name for Pure and Fresh milk and milk products. As of now, the Union has organized 1868 Dairy Co-operatives Societies (DCS) in 2425 villages, thereby covering 87% of the total village in the above districts. The firm is producing four dairy products and uses 20 facilities to produce these four dairy products. Each product is having a specific operational sequence on the facilities. The products have different routes to reach the finished stage. The plan of the existing layout of the organization under study is shown in Fig.1. The existing layout plan consists of all the facilities required to process the dairy products. On one side of the firm, there is a road with an entrance gate, and all other sides have compound walls. The side which touches the road has a 6 m wide gate. Through the gate, goods trucks can enter the diary for unloading and loading of raw materials/finished goods. The approximate size of the facilities in the plan is also given in Table 1. The maximum and minimum side lengths specified in Table 1 is after considering the work-in-process stock area requirements. These data are obtained based on the discussion with the management/workers.

4. Presentation of Case Data and Methodology to Develop New Layout

In this section, data collected from the milk diary are presented in the tables, and (SA-FBS) solution approach steps as given in Hunagund et al. [2] are presented. The facilities are identified with numbers ‘A’ to ‘W’ as given in the last column of Table 1. The operations sequence of various products with their daily demand quantity is given in Table 2. The sequence of facilities given in Table 2 is based on the operations required for the material to convert into a finished part. For example, the Milk has an operation sequence as A-B-C-D-I, It means the first operation of this product is carried out in the facility Storage Silo (A) and the second operation in the facility raw milk chiller (B) and so on. The centre-to-centre rectilinear distance between the facilities in the existing layout is measured, and these values are provided in Table 3. Products are transferred from one facility to another facility by automated flow after the completion of each operation. The volume of product flow per day between the facilities is computed based on the operation sequence and the daily demand quantity of products. The computed daily material flow between facilities is shown in Table 4.

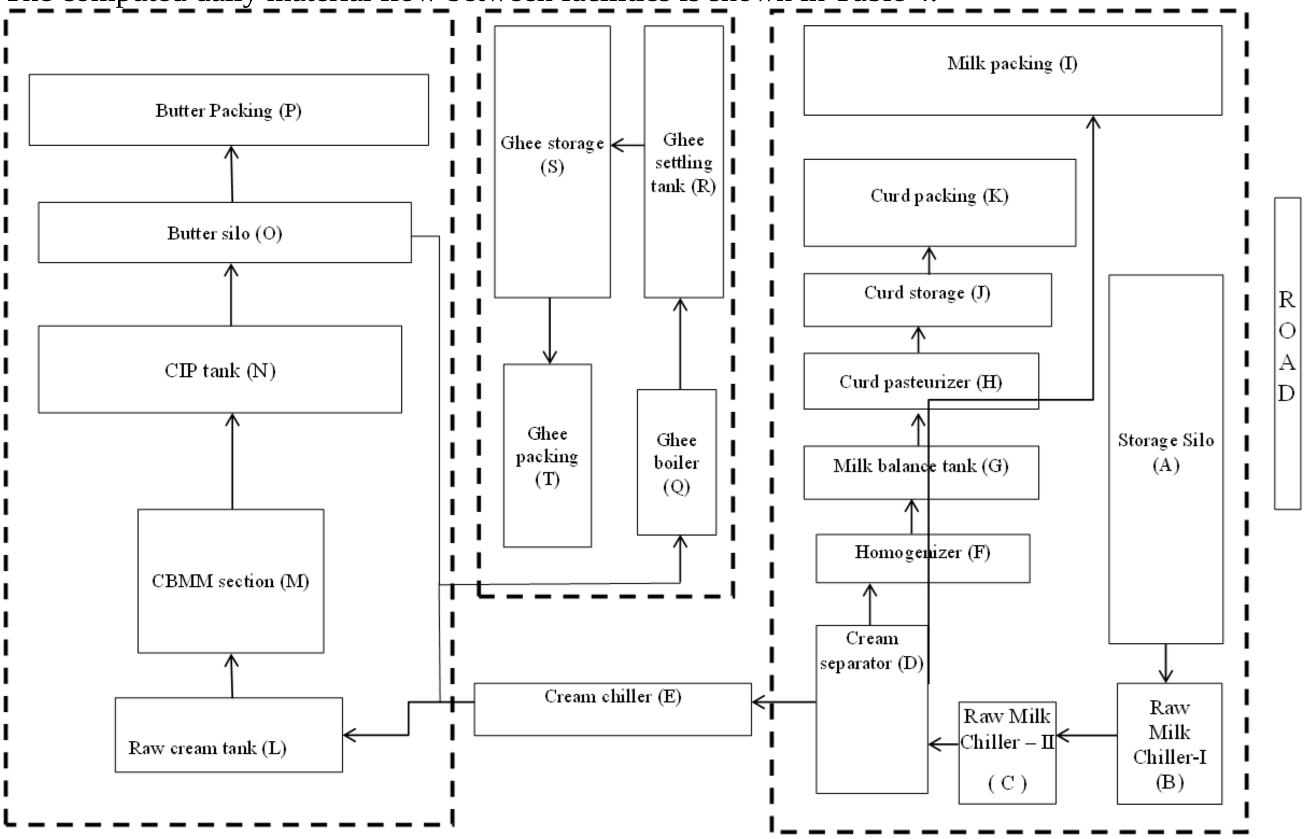

Fig. 1 Existing block layout in the plant

Table 1 Facilities Dimension (in m)

S.No	Machines	Length(L) in m	Breadth(B) in m	L*B (in m^2)	Codes
1	Storage Sailo	2.16	3.52	7.6032	A
2	Raw milk chiller	0.65	1.90	1.2350	B
3	Raw milk chiller	3.10	1.40	4.3400	C
4	Cream separator	1.40	2.40	3.3600	D
5	Cream chiller	0.65	1.30	0.8450	E
6	Homogenizer	2.25	1.90	4.2750	F
7	Milk balance tank	1.45	1.60	2.3200	G
8	Curd pasteurizer	1.78	2.18	3.8804	H
9	Milk packing	1.00	2.00	2.0000	I
10	Curd storage tank	0.68	0.81	0.5508	J
11	Curd packing	1.00	2.00	2.0000	K
12	Raw cream tank	0.80	3.60	2.8800	L
13	CBMM section	2.03	4.89	9.9267	M
14	CIP tank	2.03	1.64	3.3292	N
15	Butter sailo	0.97	4.74	4.5978	O
16	Butter packing	11.90	2.40	25.3470	P
17	Ghee boiler	1.80	2.70	4.8600	Q
18	Ghee settling tank	1.50	3.06	4.5900	R
19	Ghee storage tank	3.38	3.60	12.1680	S
20	Ghee packing	0.42	1.75	0.7350	T

Table 2 Operation sequencing order of facilities and daily demands of various products

Sl.No	Products	Operation sequences	Daily demand (in lakhs of kgs)
1	Milk`	A-B-C-D-I	8.70896
2	Curd	A-B-C-D-F-G-H-J-K	1.10031
3	Butter	A-B-C-D-E-L-M-N-O-P	1.48557
4	Ghee	A-B-C-D-E-O- Q-R-S-T	0.81140

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Table 3 Center to center distance of facilities in existing layout

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	5	6.2	10.8	6.25	7.15	8.25	16.35	12	23	10	12.3	16.21	16.30	16.50	18	17.26	17.8	17.9	11.8
2	3	0	8.6	12.8	14	4.8	8.1	14.8	11	20	10.2	9.5	13.2	13.3	13.5	15	14.2	14.8	14.9	8.8
3	6.2	8.6	0	3	8	8.7	4.5	8.9	6	9.4	7.2	12.5	10	15.2	16.7	18.2	16.2	17.2	18.3	10.8
4	10.8	12.8	3	0	10	10.8	6.65	11.9	6	5.8	4.5	10.5	8	13.2	14.6	16.1	14.2	15.3	16.2	8.4
5	6.25	14	8	10	0	6.9	2	1.7	7.3	5.4	16.4	19.5	23.4	25	27.2	28.9	18.2	17.8	18.8	12.8
6	7.15	4.8	8.7	10.8	6.9	0	6.1	16.8	11	18	10.2	7.5	11.2	15.3	15.5	17	12.26	16.5	12.8	6.7
7	8.25	8.1	4.5	6.65	2	6.1	0	3.23	10.4	4.5	15.4	17.5	20.4	23	25.1	14.1	16.2	15.8	16.8	10.8
8	16.35	14.8	8.9	11.9	1.7	16.8	3.23	0	12	7.5	10.1	19.4	22.4	25	27	16.1	18.2	17.8	18.8	12.8
9	12	11	6	6	7.3	11	10.4	12	0	5.3	2.1	11.2	17.1	18.6	19.3	20.4	21.5	22.6	23.4	24.5
10	23	20	9.4	5.8	5.4	18	4.5	7.5	5.3	0	9.5	15.5	18.4	22	22.9	13.1	15.2	14.8	16.2	9.4
11	10	10.2	7.2	4.5	16.4	10.2	15.4	10.1	2.1	9.5	0	12.3	18.1	19.6	20.3	21.4	22.5	23.6	20.4	25.4
12	12.3	9.5	12.5	10.5	19.5	7.5	17.5	19.4	11.2	15.5	12.3	0	7	9.1	11.4	13.3	15.4	17.2	19.1	20.7
13	16.21	13.2	10	8	23.4	11.2	20.4	22.4	17.1	18.4	18.1	7	0	1.9	3.9	6	10.3	11.3	12.6	13.5
14	16.3	13.3	15.2	13.2	25	15.3	23	25	18.6	22	19.6	9.1	1.9	0	1.9	2.8	4.1	5.2	6.1	7.3
15	16.5	13.5	16.7	14.6	27.2	15.5	25.1	27	19.3	22.9	20.3	11.4	3.9	1.9	0	2.5	8.2	10.3	11.2	7.8
16	18	15	18.2	16.1	28.9	17	14.1	16.1	20.4	13.1	21.4	13.3	6	2.8	2.5	0	17.3	18.4	19.3	7.8
17	17.26	14.2	16.2	14.2	18.2	12.26	16.2	18.2	21.5	15.2	22.5	15.4	10.3	4.1	8.2	17.3	0	1	3	7.8
18	17.8	14.8	17.2	15.3	17.8	16.5	15.8	17.8	22.6	14.8	23.6	17.2	11.3	5.2	10.3	18.4	1	0	2.3	7.8
19	17.9	14.9	18.3	16.2	18.8	12.8	16.8	18.8	23.4	16.2	20.4	19.1	12.6	6.1	11.2	19.3	3	2.3	0	7.8
20	11.8	8.8	10.8	8.4	12.8	6.7	10.8	12.8	24.5	9.4	25.4	20.7	13.5	7.3	7.8	7.8	7.8	7.8	7.8	0

Table 4 Product flow between facilities/day (from-to matrix)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	12.1062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	12.1062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	12.1062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	2.297	1.1003	0	0	8.709	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	1.4856	0	0	0.8114	0	0	0	0	0
6	0	0	0	0	0	0	1.1003	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	1.1003	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	1.1003	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1.1003	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	1.4856	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4856	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4856	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4856	0.8114	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8114	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8114	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8114
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.1 Developing a new layout for the case problem using the proposed two-stage solution method:
The approach to solving the case problem consists of developing the layout with a flexible bay structure by using simulated annealing for the flexible bay structure (SA-FBS) solution approach as given in Hunagund et al [2]. SA-FBS algorithm solves the unequal area facility layout problems with a flexible bay structure. The heuristic gives a better solution to layout problems with flexible bays in the layout with lesser computational timings.

4.2 SA-FBS steps of Hunagund's [2]

Step 1: *Generating initial solution and initial score:*

a. Generate feasible solution randomly and set this as initial solution S_{in}.

b. Calculate the objective function value (material handling cost) of randomly generated feasible solution and set this as initial cost TC_{in}.

c. Set Current solution, $S\_current = S_{in}$ and Current cost, $TC\_current = TC_{in}$.

f. Set Best solution, $S\_best = S_{in}$, and Best cost, $TC\_best = TC_{in}$.

Step 2: *Annealing schedule:*

a. Compute the initial temperature (T_I) for which 95% of the configuration changes are accepted at starting stage and set this as T_i.

b. Set Epoch length ($L = n^2$), Cooling ratio $\alpha = 0.98$

c. Compute final temperature T_F

Step 3: Set the outer loop for temperature decrement.

Step 4: Setting the inner loop for epoch length (L).

a. Set iteration counter $il = 1$; at each temperature.

Step 5: Generate feasible neighborhood solution (S_n) from current solution ($S\_current$) by perturbation method explained in section 4.4.

a. Compute objective function value (total score) (TC_n) of neighborhood solution S_n.

b. If $TC_n < TC\_best$ Then set, $TC\_best = TC_n$ and $S\_best = S_n$

c. Calculate the change in objective function value *(DE)*,

$DE = TC_n - TC\_current$

Step 6: If($DE<0$)

a. Set $S\_current = S_n$ and $TC\_current = TC_n$

Else

b. Generate random number (r) in the range[0...1] for metropolis criterion

If $r< e^{(-DE/Ti)}$ Then set $S\_current = S_n$ and $TC\_current = TC_n$

Step 7: If ($il < L$), Then set $il = il+1$; and go to Step 5, otherwise go to the next Step.

Step 8: Set$T_i = \alpha . T_i$;

Step 9: If ($T_i > T_F$), then go to Step 3, otherwise go to the next Step.

Step 10: Stop the program and report the results.

For the detailed encoding scheme, neighborhood search operations, and SA-FBS parameters settings one can refer to Hunagund et al [2].

5. Developing a New Layout and Discussion of Results

In the present study, the facilities size and flow matrix of case data are given as input to the SA-FBS heuristic program which is coded in MATLAB2007b to get the new layout and its material handling cost. For shape constraint, the maximum aspect ratio of **five** is considered for each facility. The block layout generated by the SA-FBS solution method without aisles is shown in Fig. 2. Table 5 gives the facilities' sizes and their centre coordinates in the newly generated layout without aisles.

The flexible bay structure layout developed by SA-FBS has seven bays in the layout. The facilities assigned to different bays and various bays width obtained by simulated annealing for flexible bay structure (SA-FBS) are as follows.

Facilities assigned in various bays by SA-FBS

Facilities assigned in the Bay 1 = 16

Facilities assigned in the Bay 2 = 17 15 20 18

Facilities assigned in the Bay 3 = 6 19

Facilities assigned in the Bay 4 = 9 14 11

Facilities assigned in the Bay 5 = 4 5 12 7 10

Facilities assigned in the Bay 6 = 3 2 13

Facilities assigned in the Bay 7 = 1 8

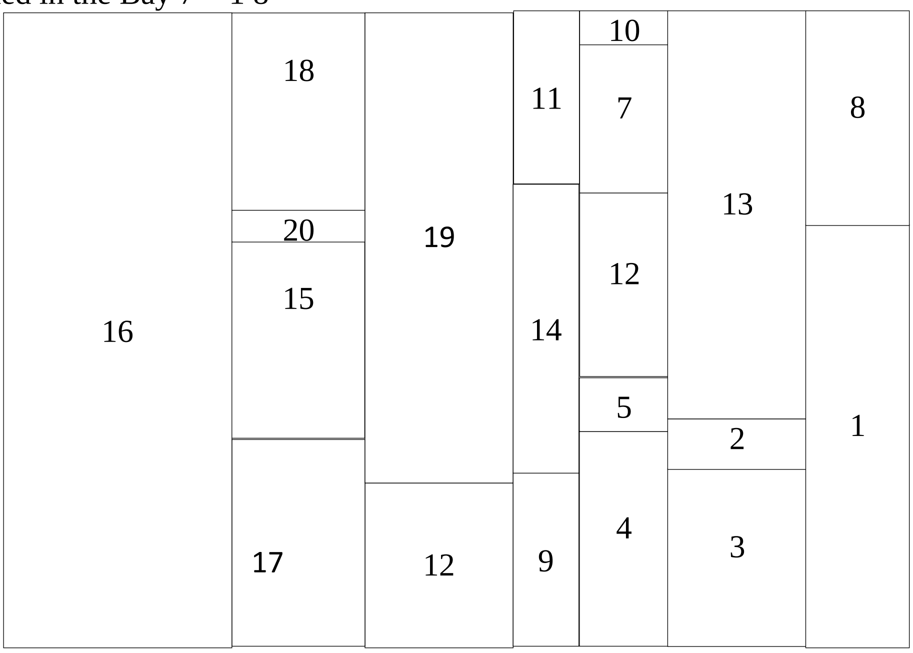

Fig. 2 New layout generated by SA-FBS without aisles for movement of men and material.

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Table 5 Facilities dimension and their center co-ordinates values in newly generated layout.

Facility No.	Dimension		Center Co-ordinate values Without aisles	
	Width	Height	X	Y
1	1.37	5.56	11.32	2.78
2	1.84	0.67	9.71	2.69
3	1.84	2.35	9.71	1.18
4	1.18	2.84	8.20	1.42
5	1.18	0.71	8.20	3.19
6	1.96	2.18	5.75	1.09
7	1.18	1.96	8.20	6.96
8	1.37	2.84	11.32	6.98
9	0.87	2.29	7.17	1.15
10	1.18	0.46	8.20	8.17
11	0.87	2.29	7.17	7.26
12	1.18	2.43	8.20	4.77
13	1.84	5.38	9.71	5.71
14	0.87	3.82	7.17	4.20
15	1.76	2.61	3.90	4.07
16	3.02	9.46	1.51	4.72
17	1.76	2.76	3.90	1.38
18	1.76	2.61	3.90	7.10
19	1.96	6.22	5.75	5.29
20	1.76	0.42	3.90	5.59

Width of various bays by SA-FBS

Bay 1 width = 3.02 m
Bay 2 width = 1.76 m
Bay 3 width = 1.96 m
Bay 4 width = 0.87 m
Bay 5 width = 1.18 m
Bay 6 width = 1.84 m
Bay 7 width = 1.37 m

The material candling cost obtained by SA-FBS per day is **Rs 1,35,361.1** and Material handling cost per annum is **135361.1*300 = Rs 4,06,08,330.**

The new layout generated by SA-FBS is without aisles for movement of men and materials hence it is not feasible to implement as it is on the shop floor. Hence we added the aisles between the bays and also between the facilities in the generated layout for the safe movement of materials and men. It is observed that the ***vertical aisles width of 2.5 m*** between the bays and ***horizontal aisles width of 1.5 m*** between the facilities would be sufficient for the safe movement of men and materials. The layout obtained after adding the aisles space for the movement of men and materials is shown in Fig. 3. Table 6 gives the facilities' centre coordinates in the newly generated layout with aisles in the final layout. The material handling cost obtained after adding vertical and horizontal aisles to the SA-FBS generated layout is **Rs 3,38,943.6 per day**. Material handling cost per annum is **3,38,943.6 * 300 = Rs 10,16,83,080.**

5.1 Computing the material handling cost of the existing layout in the diary:

The Material Handling Cost (MHC) of the existing layout per day is calculated using parts flow volume (f_{mn}) between facilities *m* and *n* per year (i.e. data from Table 4) data, and distances (D_{mn}) between facilities *m* and *n* in the existing layout (i.e. data from Table 3). The formula for MHC calculation is:

$$MHC = \sum_{m=1}^{N}\sum_{n=1}^{N} C_{mn} f_{mn} D_{mn} \qquad (1)$$

Where N = total number of facilities = 20.

Assuming 1 paisa of amount is required to move 1 kg of product for 1meter distance (i.e., C_{mn} = 0.01). The daily material handling cost of the existing layout for the case data using equation (1) is turn out to be **Rs 4,03,498.8/day.**

MHC = 12.1062*5+12.1062*8.6+12.1062*3+2.297*10+1.1003*10.8+8.709*6+1.4856*19.5+0.8114*27.2+1.1003*6.1+1.1003*3.23+1.1003*7.5+1.1003*9.5+1.4856*7+1.4856*1.9+1.4856*1.9+1.4856*2.5+0.8114*8.2+0.8114*1+0.8114*2.3+0.8114*7.8)*0.01= Rs 403498.8 /day

Assuming 300 working days in a year, then the existing material handling cost per annum is **403498.8*300 = Rs 12,10,49,640.**

5.2 Comparing the material handling cost of the existing layout with newly generated layout:

The material handling cost of new Layout generated by SA-FBS = **Rs 10,16,83,080**

The material handling cost computed for existing Layout **= Rs 12,10,49,640**

Percentage savings without considering rearrangement cost

= (12,10,49,640 - 10,16,83,080)/ 12,10,49,640*100 = **16%**.

Table 6 Facilities dimension and their center co-ordinates values in newly generated layout with aisles in the layout.

Facility No.	Dimension		Center Co-ordinate values with aisles in the layout	
	Width	Height	X	Y
1	1.37	5.56	26.32	2.78
2	1.84	0.67	22.21	4.185
3	1.84	2.35	22.21	1.18
4	1.18	2.84	18.2	1.42
5	1.18	0.71	18.2	4.695
6	1.96	2.18	10.75	1.09
7	1.18	1.96	18.2	11.46
8	1.37	2.84	26.32	8.48
9	0.87	2.29	14.67	1.15
10	1.18	0.46	18.2	14.17
11	0.87	2.29	14.67	10.255
12	1.18	2.43	18.2	7.765
13	1.84	5.38	22.21	8.71
14	0.87	3.82	14.67	5.7
15	1.76	2.61	6.4	5.565
16	3.02	9.46	1.51	4.72
17	1.76	2.76	6.4	1.38
18	1.76	2.61	6.4	12.45
19	1.96	6.22	10.75	6.79
20	1.76	0.42	6.4	8.58

To implement the newly developed layout given in Fig 3, rearrangement of existing facilities is to be made. The maximum rearrangement cost considered in the literature for relocating the facilities is 20% of the annual material handling cost. Hence in the present study, we consider the one-time rearrangement cost of facilities as 15% of the total material handling cost in a year. Therefore, the one-time rearrangement cost is **= 0.15 × 10,16,83,080** = **Rs 1,52,52,462**. The total material handling cost including rearrangement cost for the first year comes out to **Rs 11,69,35,542** (10,16,83,080 + 1,52,52,462), which is still less than the one year material handling cost of the existing layout **(**i.e., Rs 12,10,49,640/annum**)**. Hence after considering the production loss, rearrangement cost, and material handling cost, the returns can be expected from the second year if the re-layout is done as per the results obtained from the SA-FBS solution method. If the company adapts the new layout then from the second year onwards the expected yearly savings from the new layout would be **Rs 1,93,66,560** (i.e., 12,10,49,640 -10,16,83,080). Hence the newly generated layout has given lesser material handling cost, better space utilization and also provided a safer shop floor for movement of men and materials.

6. Conclusion

The case study indicates the importance of layout design in reducing the operating cost of a firm. In the present work, the existing Simulated Annealing for Flexible Bay Structure (SA-FBS) heuristic approach to layout formation in a static environment is used.

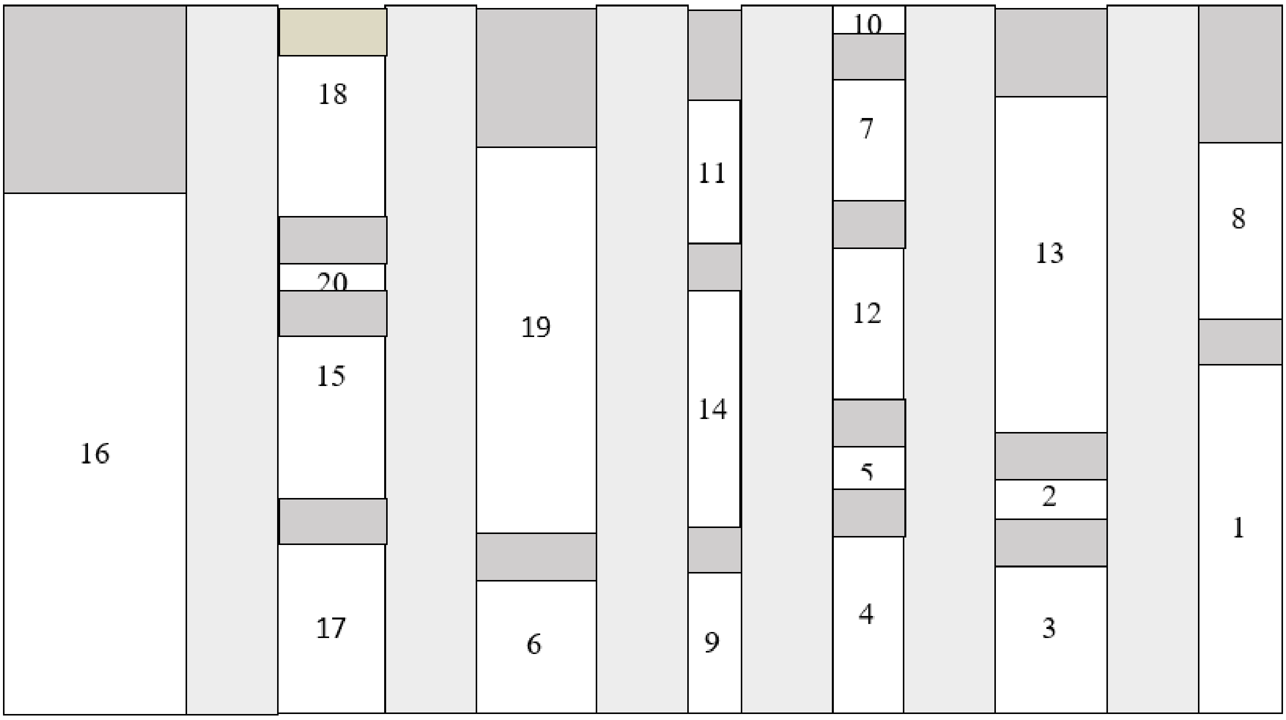

Fig. 3 New generated SA-FBS layout with adding aisles space for movement of men and material

The material handling cost of the new layout obtained by the SA-FBS heuristic algorithm is a promising one as compared to the existing layout material handling cost in the company. In conclusion the solution obtained by using the SA-FBS approach of Hunagund et al [2] has not only given a lesser material handling cost but also provided a safer shop floor for the movement of men and materials. The present work considers the static unequal area layout formation with flexible bays in the layout. In the future, dynamic data can be collected and dynamic environment solution approaches can be considered for unequal area layout formation with flexible bay structure in the layout.

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