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Improving Capacity Utilisation in Bread Processing Factories Using the BLOCPLAN Algorithm

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Abstract

Numerous factors are causing small and medium enterprises (SMEs) to close at an alarming rate worldwide. The faulty manufacturing and management setup made the system costly and wasteful. Detailed research into the causes of these collapses made the factory layout issue important to this study. This research aims to examine the current floor plans for bakeries to increase capacity utilization, enhance the production efficiency for the firms, and increase profit using the BLOCPLAN (Block Layout Overview with Layout Planning) algorithm software. Measured and recorded were the rectilinear distances between the manufacturing workstations at three bakeries situated in Warri, Nigeria. This was achieved by closely monitoring the production process and using a stopwatch. The initial production area was determined in square metres by measuring and recording the length and width of the manufacturing equipment. The rectilinear distances for Bakery A, B, and C are 13.9, 17.4, and 21.1 metres, respectively, based on measurements. For bakeries A, B, and C, the associated production throughput times were 48 minutes, 76 minutes, and 81.5 minutes, respectively. 987.92 m^2, 1,088.46 m^2, and 786.434 m^2 make up the combined production areas of bakeries A, B, and C. Using the BLOCPLAN, 20 iterations were carried out at each bakery, and the iteration with the best R-score for each bakery was deployed as the best alternative layout. The R-Score results were 0.81, 0.64, and 0.91 for bakeries A, B, and C respectively. As a result, the effectiveness of bakeries A, B, and C received a boost of 58.3%, 52.8%, and 67.3%. The results obtained from this work show that optimizing the facility layout of a typical bread production factory using the BLOCPLAN technique could increase production capacity and improve overall system performance.

Keywords: Activity Relationship Chart, BLOCPLAN, Factory Layout, Optimization

1. INTRODUCTION

Particularly in Nigeria, the rate at which industries fail is alarming. Entrepreneurs start new businesses without first analyzing why others are failing. Almost every family relies on bread as a daily diet staple because it is a fast-moving consumer good. This made this study necessary because properly optimized production systems ensure that bread factories have no reason to fail. The study therefore focused on improving capacity utilisation in three bread production factories through factory layout using BLOCPLAN algorithm software.

The Genetic Algorithm GA has been applied to facility layout planning to improve facility layout by reducing the total distance travelled by materials handling equipment (Garcia et al., 2018; Halawa et al., 2021; Liu et al., 2020; Mohamadi et al., 2018; Pourvaziri et al., 2022; Vitayasak et al., 2019; Yang & Lu, 2023).

The Simulated Annealing Algorithm (SA) is another algorithm that can be applied to modelling facility layout. Finding a function's global optimum is done using a probabilistic algorithm. By reducing the overall distance travelled by materials handling equipment, the SA algorithm has been used in facility layout planning to optimize the layout of facilities (Ahmadi-Javid & Ardestani-Jaafari, 2021; Halawa et al., 2021; Kubalík et al., 2023; Mallikarjuna et al., 2016; Mohamadi et al., 2018).

The BLOCPLAN (Block Layout Overview with Layout Planning) has been implemented for facility layout planning in some published reports (Azhar, 2021; Imanullah et al., 2021; Puspita et al., 2017; Siregar et al., 2020).

In this study, the BLOCPLAN algorithm was deployed for the bread processing factory layouts to improve capacity utilization.

2. METHODOLOGY

2.1 Materials

The research was conducted at three large-scale bread factories (Bakery A Located at Third Marine Gate, Effurun-Sapele Road; Bakery B located at Aka Road and Bakery C located at Mode Road, all in Warri, Delta State). The original plant arrangement of the Bakeries used for bread making is considered to be below capacity for the production capacity of up to 2000 kg, 2700 kg, and 3,200 kg daily hence this study. Data were collected during the technical visits to the bakeries.

2.2 Study Design and Methods

The steps taken in this study were to review the previous reports and conduct surveys for the majority of publications that dealt with layout. The BLOCPLAN (Block Layout Overview with Layout Planning) algorithm was used for the design implementation, the best layout option is determined using the R-Score with the highest value. The BLOCPLAN layout analysis was carried out with the BLOCPLAN software. The results of the initial conditions, identification, and measurement were used as input. The best facility layout with the best R-Score results was selected. Figure 1 shows a summary of the research methodology adopted for the BLOCPLAN Facility Layout optimization.

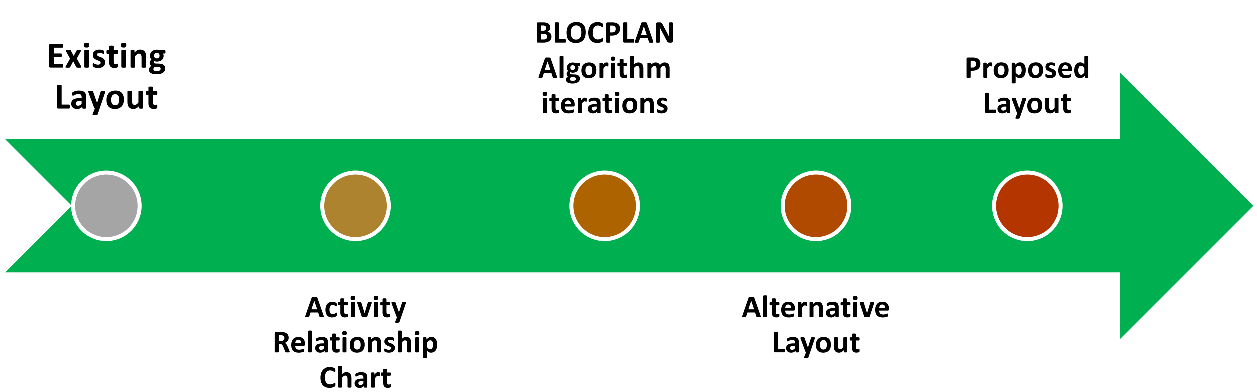

Figure 1. Research Methodology through BLOCPLAN Application

2.3 The Bread Processing Stages at Bakeries A, B and C

The production facilities/units of Bakeries A, B and C include Milling, Scaling, Dividing, Moulding, Creaming, Panning, Cupping, Stacking, Oven Backing, Packaging and Storage. Measuring the distance of material movement allows one to calculate the distance between production facilities. According to Imanullah et al., (2021), The equation for calculating displacement distance using a rectilinear distance system is as follows:

$$\boldsymbol{d_{ij} = |x_i - x_j| + |y_i - y_j|} \tag{1}$$

Where

d_{ij} = distance between workstations i and j, x_i = x-coordinate at the middle of the facility i

x_j = x-coordinate at the middle of the facility j, y_i = y-coordinate at the middle of the facility i

y_j = y-coordinate at the middle of the facility j.

2.4 Total Production Facility Area

The following formula can be used to calculate the total area of the facility used for production (Imanullah et al., 2021).

$$\text{The total area of the facility used for production} = (\text{plant area} \times \text{N}) + \text{allowance} \tag{2}$$

Where

N is the number of allowances provided for the machine (m^2)

Each plant or other equipment is given a tolerance of 0.75 m on each side.

Therefore, the plant area can be obtained from (Imanullah et al., 2021).

$$\text{Machine area} = (0.75\ \text{m} + \text{L} + 0.75\ \text{m}) \times (0.75\ \text{m} + \text{W} + 0.75\ \text{m}) \tag{3}$$

Where

$\text{L} = \text{Machine length (m)}$,

$\text{W} = \text{Machine breadth (m)}$

2.5 Normal Time

According to Imanullah et al., (2021), the production process' normal time is determined by taking the adjustment factor into account.

$$W_n = (W_s * p) \quad (4)$$

Where

W_n = normal time (seconds), W_s =cycle time (seconds) and p = Westinghouse method correction coefficient.

2.6 Standard Time

The operator's standard time is the amount of time needed to create one product unit. The tolerance for rest and unavoidable factors must be taken into account when setting the standard time for each production process. The formula shown below is used to determine the standard time (Imanullah et al., 2021).

$$W_b = W_n(1 + i) \quad (5)$$

Where

W_b = standard time (seconds),W_n = normal time (seconds),I = allowance

2.7 Activity Relationship Chart (ARC)

According to Sharma & Mor (2015), a rating system called closeness ratings is used to describe the relationship. The closeness rating between activities is always justified. Any number of factors, including material flow and the need for contact, could be to blame. Table 1 shows the closeness rating and Table 2 the reason for the closeness ratings.

Table 1. Closeness Rating

Rating	Closeness
A	Absolutely necessary
E	Especially important
I	Important and core
O	Ordinary
U	Unimportant
X	Prohibited /Undesirables

Table 2. Reasons for the Closeness Ratings

Code	Reason
1	Flow of material
2	Ease of Supervision
3	Common Personnel
4	Necessary Contact
5	Noise
6	Similar Pieces of Equipment

3. RESULTS AND DISCUSSIONS

3.1 Production Plant Area for Bakery A, B and C.

The necessary amount of space for production facilities was determined using equation (3). A calculation was made to determine the size of the Bakeries production facilities, and the results are displayed in Tables 3-5.

Table 3. Equipment and Total Production Facility Area for Bakery A

Machine/Equipment/Workstations	Dimensions $L \times W$ (m^2)	Quantity	Total production facility area (m^2)
Bread Millers (Milling)	0.188 × 0.0151	3	10.49
Weighing scale (Scaling)	0.7 × 0.7	1	3.08
Bread mould (Moulding)	0.15 × 0.10	200	650.88
Dough mixer (Mixing)/Dividing	0.875 × 0.485	3	13.96
Creamer (Creaming)	0.18 × 0.10	2	2.69
Cupping/Panning/Stacking	1.2 × 1.868	1	2.242
Oven	0.61 × 0.686	2	9.472
Bread Slicing	0.47 × 0.14	2	8.1
Baking Cooling rack (Packaging)	0.405 × 0.255	4	15.52
Storage	10× 7	1	70
GRAND TOTAL			**786.434**

Table 4**.** Equipment and Total Production Facility Area for Bakery B

Machine/Equipment/Workstations	Dimensions $L \times W$ (m^2)	Quantity	Total production facility area (m^2)
Bread Millers (Milling)	0.196 × 0.0145	4	**11.16**
Weighing scale (Scaling)	0.85 × 0.85	2	**11.05**
Bread mould (Moulding)	0.15 × 0.10	280	**739.2**
Dough mixer (Mixing)/Dividing	0.795 × 0.59	4	**19.17**
Creamer (Creaming)	0.21 × 0.15	3	**8.47**
Cupping/Panning/Stacking	1.25 × 1.795	2	**9.06**
Oven	0.81 × 0.768	3	**15.72**
Slicing Machine	0.55 × 0.16	3	**10.20**
Baking rack (Packaging)	0.605 × 0.30	6	**22.14**
Storage	12× 9	1	**141**
GRAND TOTAL			**987.92**

Table 5. Equipment and Total Production Facility Area for Bakery C

Machine/Equipment/Workstations	Dimensions $L \times W (m^2)$	Quantity	Total production facility area(m^2)
Bread Millers (Milling)	0.20 × 0.18	5	**14.28**
Digital Scale	0.90 × 0.90	2	**11.52**
Bread Moulds	0.15 × 0.10	300	**792**
Bread mixer /Dividing	0.90 × 0.60	4	**20.16**
Creamer (Creaming)	0.29 × 0.16	4	**5.94**
Cupping/Panning	1.4 × 1.95	1	**10.01**
Oven	01.25 × 0.98	4	**27.28**
Slicing Machine	0.85 × 0.19	4	**15.89**
Cooling rack (Packaging)	1.96 × 0.68	6	**22.63**
Storage	11× 12	1	**168.75**
GRAND TOTAL			**1,088.46**

3.2 The Rectilinear Distances between workstations

The rectilinear distance between the workstations in the respective bakeries were calculated using equation (1) and reported in Tables 6-8.

Table 6. Rectilinear Distances Between workstations in the initial layout of Bakery A

Production facility	Distance (meters)
Milling to Scaling	0.8
Scaling to dividing	1
Dividing to Dough moulding	0.8

Dough moulding to creaming	0.8
Creaming to panning and staking	1.2
Staking to oven	2.8
Oven to packaging	4.2
Packaging to stores/awaiting sales	2.3
TOTAL	**13.9**

Table 7. Rectilinear Distances Between workstations in the initial layout of Bakery B

Production facility	Distance (meters)
Milling to Scaling	1.4
Scaling to dividing	1.6
Dividing to moulding	1.7
Dough moulding to creaming	1.6
Creaming to staking	1.8
Staking to oven baking	3.2
Oven to packaging	3.8
Packaging to stores/awaiting sales	2.3
TOTAL	**17.4**

Table 8. Rectilinear Distances Between workstations in the initial layout of Bakery C

Production facility	Distance (meters)
Milling to Scaling	1.2
Scaling to dividing	1.9
Dividing to Bread moulding	1.8
Bread moulding to creaming	1.4
Creaming to staking	2.2
Staking to oven baking	4.8
Oven to packaging	4.2
Packaging to stores/awaiting sales	3.6
TOTAL	**21.1**

3.3 Activity Relationship Chart (ARC)

The ARC was computed for the ten Departments/workstations in the Bread Production factories using MS Excel as shown in Table 9. The closeness rating and the codes for the ten departments and workstations were represented as described in Tables 1 and 2.

Table 9. Activity Relationship Chart for the Production of Bread

Departments	1	2	3	4	5	6	7	8	9	10

1	**Bread Milling**		O/3	A/1	O/3	I/1	U/3	X/4	O/3	U/3	U/3
2	**Scaling**	O/3		O/3	A/1	A/1	U/3	U/3	U/3	U/3	U/3
3	**Dividing**	A/1	O/3		A/1	I/1	O/3	X/4	U/3	U/3	U/3
4	**Moulding**	O/3	A/1	A/1		I/1	A/1	X/4	O/3	U/3	U/3
5	**Creaming**	I/1	A/1	I/1	I/1		O/3	U/3	U/3	U/3	U/3
6	**Panning/Stacking**	U/3	U/3	O/3	A/1	O/3		I/1	A/1	A/1	O/3
7	**Oven**	X/4	U/3	X/4	X/4	U/3	I/1		U/3	U/3	X/4
8	**Slicing**	O/3	U/3	U/3	O/3	U/3	A/1	U/3		A/1	U/3
9	**Packaging**	U/3	U/3	U/3	U/3	U/3	A/1	U/3	A/1		A/1
10	**Store**	U/3	U/3	U/3	U/3	U/3	O/3	X/4	U/3	A/1	

3.4 BLOCPLAN (Single-Story) Result for Bakeries

The ARC for the bakeries obtained in Table 9 were inputed in the BLOCPLAN software as shown in Figure 2. The L/W ratio of 1.35 × 1.00 was chosen for the layout design. A total of 20 iterations was conducted for each factory and the best layout with the greatest R-score were selected for the respective bakeries. Table 10 shows the various iterations for the layouts and the best R-Scores highlighted. The best iterations for the bakeries A , B and C are represented in BLOCPLAN as shown in Figures 3-5. The alternative rectilinear distances for the new layouts are shown in Tables 11-13.

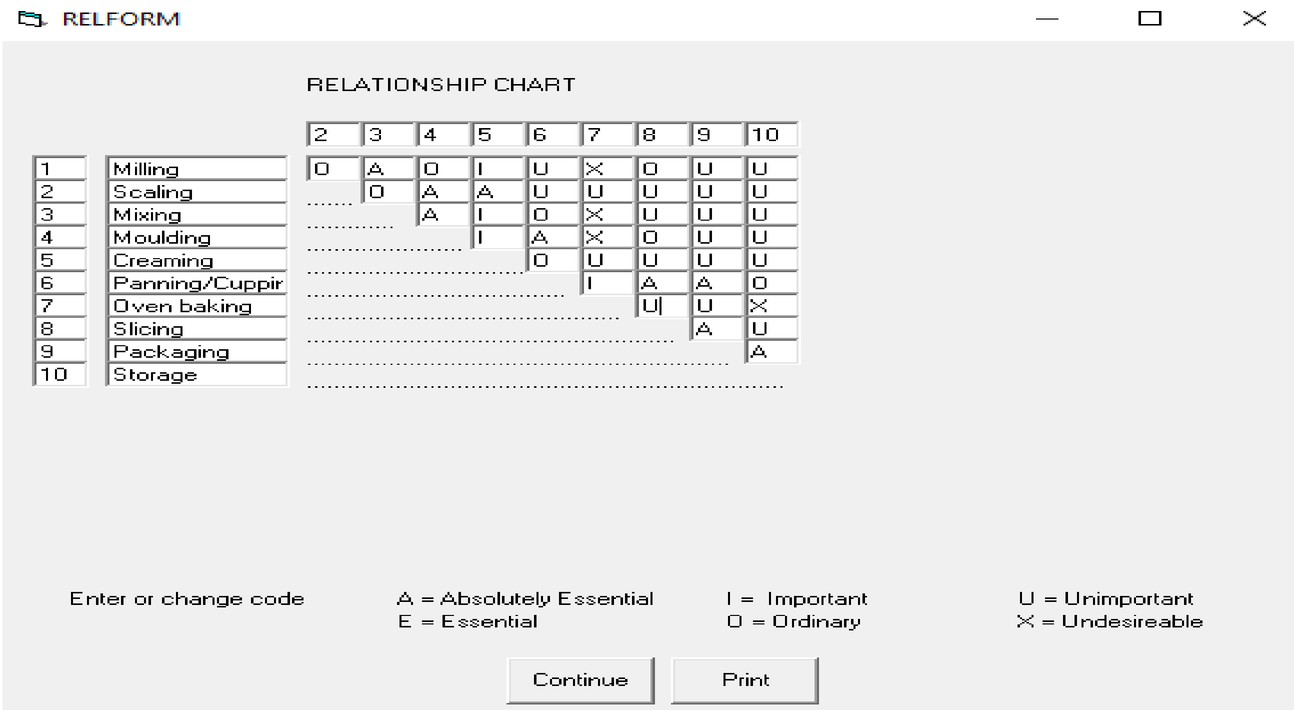

Figure 2. BLOCPLAN for the relationship chart for Bakeries

Table 10. Arbitrary iteration Results of the three Bakeries.

ITERATION	R-SCORE BAKERY A	R-SCORE BAKERY B	R-SCORE BAKERY C
1	0.16	0.35	0.25
2	0.35	0.15	0.07
3	0.46	0.18	0.26
4	0.55	**0.64**	0.37
5	0.57	0.25	**0.91**
6	0.58	0.15	0.25
7	0.46	0.43	0.14
8	0.55	0.28	0.16
9	0.65	0.15	0.42
10	0.62	0.33	0.34
11	**0.81**	0.45	0.36
12	0.73	0.24	0.07
13	0.70	0.25	0.54
14	0.75	0.08	023
15	0.66	0.28	0.06
16	0.59	0.15	0.32
17	0.71	0.26	0.31
18	0.48	0.19	0.33
19	0.69	0.28	0.06
20	0.77	0.29	0.52

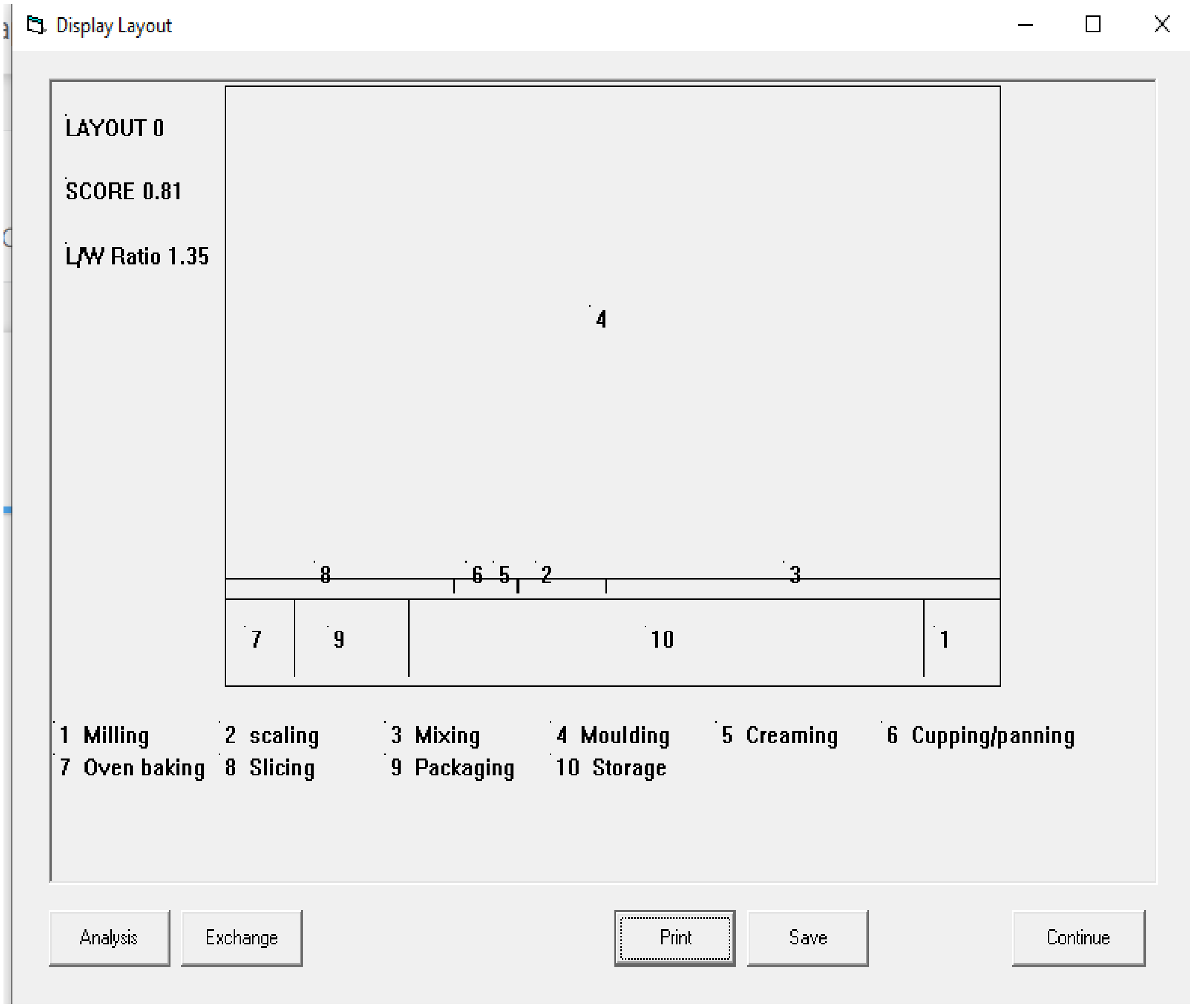

Figure 3. Best Iteration for Bakery A with an R score of 0.81 and L/W ratio of 1.35

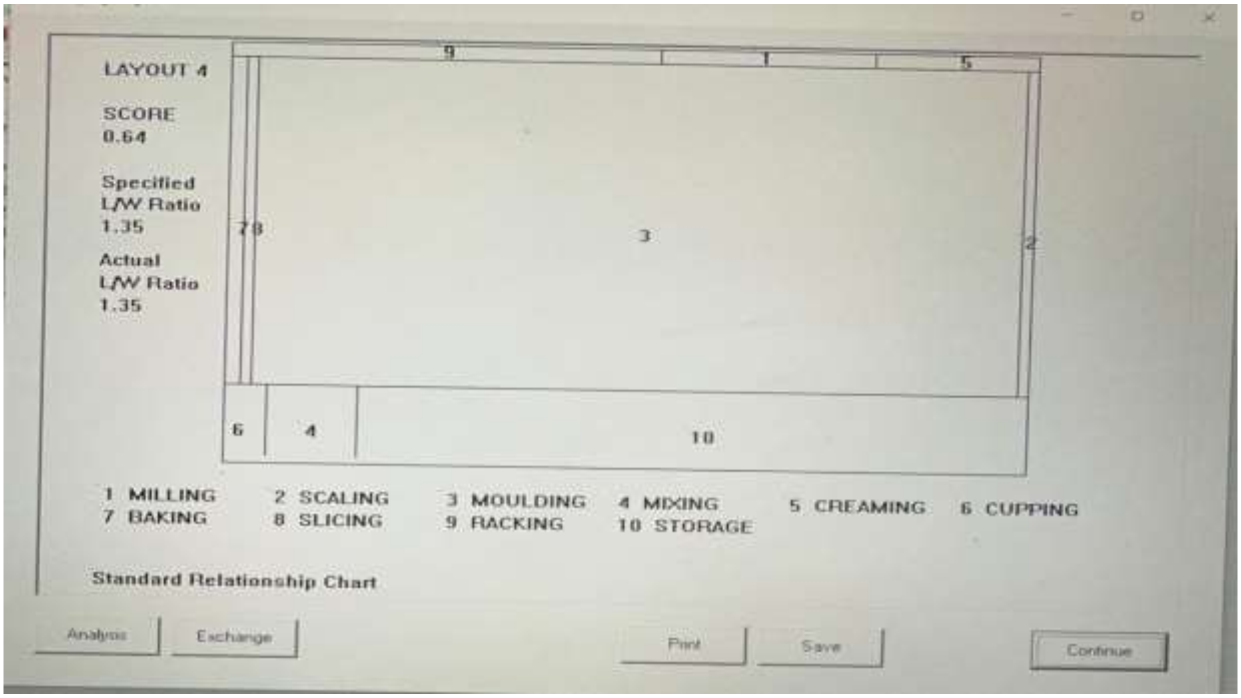

Figure 4. Best Iteration for Bakery B with an R score of 0.64 and L/W ratio of 1.35

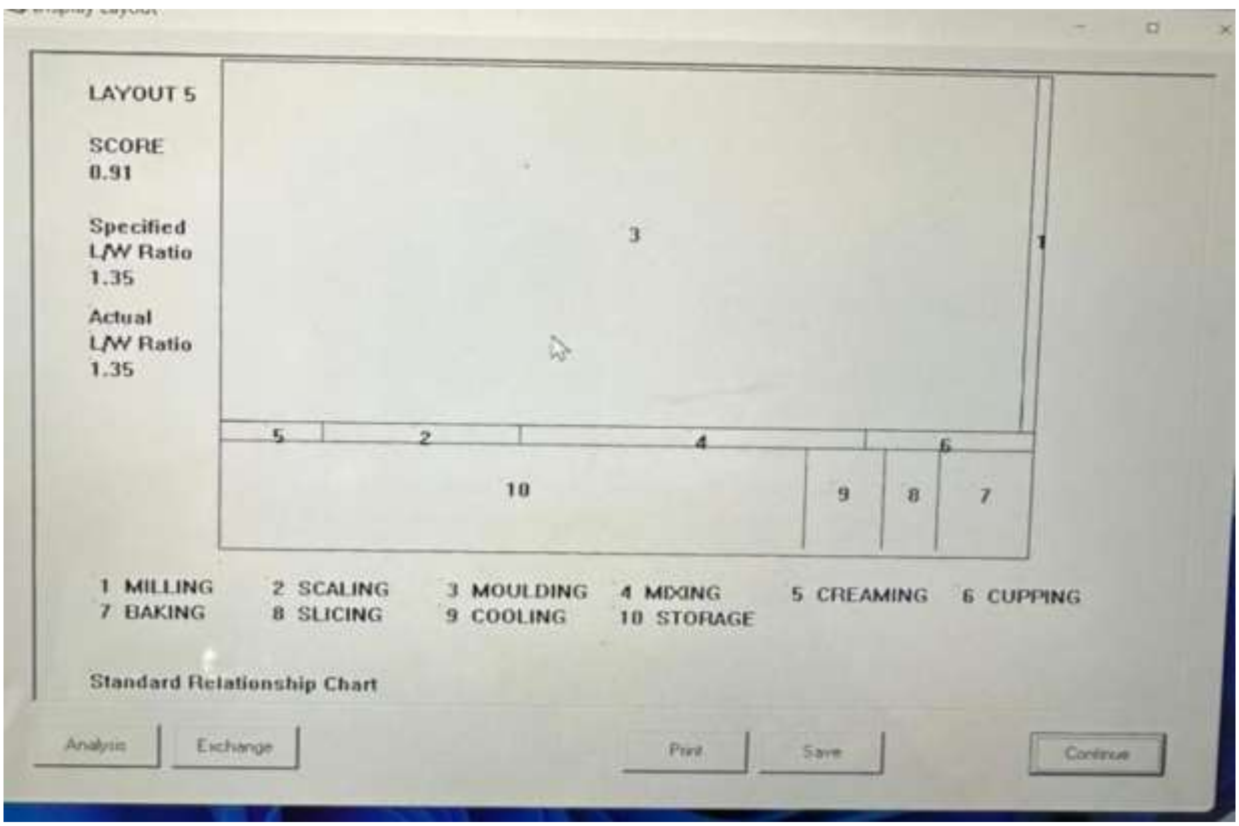

Figure 5. Best Iteration for Bakery C with an R score of 0.91 and L/W ratio of 1.35

Table 11. Rectilinear Distances Between Workstations for the Alternative Layout in Bakery A

Production facility	Distance (meters)
Milling to Scaling	1.2
Scaling to Dividing	0.8
Dividing to Bread moulding	0.8
Creaming to panning/stacking	0.5
Panning/staking to oven baking	1.2
Oven to slicing	0.8
Slicing to Packaging	1.0
Packaging to stores/awaiting sales	1.0
TOTAL	**8.1**

Table 12**.** Rectilinear Distances Between workstations in the alternative layout of Bakery B

Production facility	Distance (meters)
Milling to Scaling	0.8
Scaling to dividing	1.0
Dividing to Bread moulding	1.0
Bread moulding to creaming	1.0
Creaming to staking	1.2
Staking to oven baking	1.3
Oven to packaging	1.4
Packaging to stores/awaiting sales	1.5
TOTAL	**9.2**

Table 13. Rectilinear Distances Between workstations in the alternative layout of Bakery C

Production facility	Distance (meters)
Milling to Scaling	0.5
Scaling to dividing	1.0
Dividing to Bread moulding	0.9
Bread moulding to creaming	0.6
Creaming to staking	1.3
Staking to oven baking	3.9
Oven to packaging	3.3
Packaging to stores/awaiting sales	2.7
TOTAL	**14.2**

4. CONCLUSION

The results obtained from this work show that optimizing the facility layout of a typical bread production factory using the BLOCPLAN technique could increase production capacity and improve overall system performance. After 20 iterations on each of the layouts of the bakeries as displayed in Table 10. The iteration with the highest R-score for each of the bakeries was chosen as shown in Figures 3, 4 and 5 respectively. For Bakery A, the rectilinear distance of the proposed layout is 8.1 meters, which is an improvement from the initial distance of 13.9 meters and a reduction in material travel time from 48 minutes to 27 minutes which is a 58.3% rectilinear improvement. For Bakery B, the rectilinear distance of the proposed layout is 9.2 meters, which is an improvement from the initial distance of 17.4 meters and a reduction in material travel time between production facilities from 76 minutes to 45.6 minutes, which is a 52.8% rectilinear improvement and also the alternative rectilinear distance for Bakery C is 14.2 meters which is also an improvement from the initial layout rectilinear distance of 21.1 meters and an improvement in travel time from 81.5 minutes to 46.27 minutes which is 67.3% rectilinear improvement.

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