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Analysis of Bread Production Facilities Layout using BLOCPLAN Algorithm

Analisis Tata Letak Fasilitas Produksi Roti dengan Algoritma BLOCPLAN

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Abstract

This study aims to obtain an optimal facility layout by considering the distance between the workstations, transfer time, and material handling cost in a bakery. The research was conducted at a medium-scale bread producer CV Mumtaz Bakery in Banjarbaru City, South Kalimantan. The initial layout of CV Mumtaz Bakery's production facilities is considered as not optimal for production capacity up to 500 kg per day. The layout analysis and the appearance of improvement alternatives were carried out using the BLOCPLAN algorithm, and then the design implementation was carried out using CorelDraw software. Determination of the best layout alternative is based on the highest R-Score. The results showed that the best layout was the one with an R-Score of 0.86. This selected workstation layout has a total distance between processing stations of 31.70 m, a total transfer time of 25 seconds, and a material handling cost of IDR 434.29 for each batch. This layout will reduce the total material transfer distance and the material transfer time from the initial layout by 14.67% and 10.7% respectively.

Keywords: BLOCPLAN, bread production, facilities layout, material handling cost

Abstrak

Penelitian ini bertujuan untuk memperoleh alternatif tata letak fasilitas yang lebih optimal dengan mempertimbangkan jarak antar proses produksi, waktu perpindahan, serta biaya penanganan bahan pada sebuah bakery. Penelitian dilakukan di CV Mumtaz Bakery yang merupakan produsen roti skala menengah di Kota Banjarbaru, Kalimantan Selatan. Tata letak fasilitas produksi CV Mumtaz Bakery dinilai masih belum optimal untuk kapasitas produksi hingga 500 kg per hari. Analisis tata letak dan penentuan alternatif perbaikan dilakukan menggunakan algoritma BLOCPLAN kemudian implementasi desain dilakukan dengan software *CorelDraw. Penentuan alternatif tata letak terbaik berdasarkan pada R-Score tertinggi. Hasil penelitian menunjukkan bahwa tata letak terbaik adalah alternatif dengan R-Score sebesar 0,86. Tata letak fasilitas yang terpilih tersebut mempunyai total jarak antar fasilitas produksi sebesar 31,70 m, total waktu perpindahan 25 detik, dan biaya penanganan bahan Rp434,29 untuk setiap* batch*. Penerapan tata letak ini akan menurunkan total jarak perpindahan material dan waktu perpindahan bahan dari tata letak awal secara berturut-turut sebesar 14,67% dan 10,7%.*

Kata kunci: *BLOCPLAN, biaya penanganan bahan, produksi roti, tata letak fasilitas*

INTRODUCTION

Production facility layout arrangement in a manufacturing industry is essential to minimalize resource loss, so the invested facility can function optimally (Casban & Nelfiyanti, 2019). The production facility layout arrangement is also critical in a bakery whose varies in products and processes. A bakery is a place that produces and sells flour-based food baked in the oven, such as bread, cakes, pastries, and pies. The optimal arrangement of production facilities will increase the production process's smoothness and reduce the distance and time of the material handling process (Paillin, 2013). A good production facility design can increase effectiveness and efficiency by minimizing material transfer distances and material handling costs (Rauan, Kindangen, & Pondaag, 2019). Sustainable development is vital, and there is always room for increasing efficiency of production facilities layout, including redesigning the production process layout (Devi & Seto, 2017).

Redesigning production process analysis can be carried out using the BLOCPLAN algorithm approach, a mathematical model compiled in a computer application. BLOCPLAN is an algorithm developed for facility layout design using a hybrid algorithm that combines a constructive algorithm and a repair algorithm. BLOCPLAN considers the degree of proximity between workstations, builds or changes the layout by finding the minimum materials' movement total distance, and the fast output process in finding the best solution (Leonardo & Hutahaean, 2014). The best alternative selection from the BLOCPLAN algorithm output was selected based on three criteria: adjacency score, R-score, and product movement (Daya et al., 2019). Adjacency score describes the weight of proximity between facilities. The adjacency score is then correlated with the product movement value or material movement distance. The R-score shows the layout efficiency value (Jaya, Nuryati, & Audinawati, 2017).

Several researchers have conducted research related to facility layout redesign in food and beverage companies using the BLOCPLAN algorithm (Pratiwi, Muslimah, & Aqil, 2012; Siregar, Sukatendel, & Tarigan, 2013; Mustofa & Susanty, 2014; Amalia, Ariyani, & Noor, 2017; Setiyawan, Qudsiyyah, & Mustaniroh, 2017). All of these studies show that the BLOCPLAN algorithm is useful in redesigning the facility's layout to make it more efficient in terms of total distance and transfer time. This study aims to obtain a more optimal facility alternative layout by considering the distance between the production processes, transfer time, and the material handling cost in a bakery.

METHODS

This research was conducted at CV Mumtaz Bakery, a bread processing factory with 500 kg/day production capacity in Banjarbaru City, South Kalimantan. The initial layout arrangement of production facilities at CV Mumtaz Bakery does not consider efficiency aspects which causes waste due to material transfer distance and inefficient use of labor. The facility layout redesign is carried out through the physical arrangement of production machines, equipment, and workstations. The redesign of this production facility refers to the production process of peeled white bread, whose production process stages are the basic process of various kinds of bread production. The observation research method was carried out through several stages: production process identification, initial facility layout mapping, production facility area calculation, production time measurement, the calculation of material transfer time, the distance between production facilities, and material handling costs. The initial conditions identification and measurement results were then used as input in the BLOCPLAN algorithm layout analysis using BPLAN90 software. The R-Score is used as the basis for selecting the best facility layout which leads to more efficient production at CV Mumtaz Bakery. The implementation of the selected layout is then carried out using the CorelDraw application.

Distance Between Production Facilities

The distance between production facilities is determined by measuring the distance of material movement. The equation for measuring displacement distance using a rectilinear distance system is as follows (Purnomo, 2004):

$$d_{ij} = |x_i - x_j| + |y_i - y_j| \quad (1)$$

where,
d_{ij} = distance between production facilities i and j
x_i = x-coordinate at the center of facility i
x_j = x-coordinate at the center of facility j
y_i = y-coordinate at the center of facility i
x_j = y-coordinate at the center of facility j

Total Production Facility Area

The total production facility area is calculated based on machine or equipment area dimensions times with the number of machines or equipment used then added with the allowance factor. Allowances are given to provide space for machine operators when operating and carrying out repairs or maintenance and aisles as a way between production facilities. The area of production facilities can be calculated as follows (Purnomo, 2004):

$$\text{Total production facility area} = (\text{machine area} \times n) + \text{allowance} \quad (2)$$

where,
n = number of machines
allowance = operator allowance (m^2)

Each machine or supporting equipment is given a tolerance of 0.75 m on each side so that the machine area can be calculated by the following equation (Purnomo, 2004):

$$\text{Machine area} = (0.75\text{ m} + l + 0.75\text{ m}) \times (0.75\text{ m} + w + 0.75\text{ m}) \quad (3)$$

where,
l = machine length (m)
w = machine width (m)

Data Adequacy Test

The adequacy of the observation data amount during the production process is calculated using the following equation (Sutalaksana et al., 2006):

$$N' = \left(\frac{40\sqrt{N\sum x_i^2-(\sum x_i)^2}}{\sum x_i}\right) \quad (4)$$

where,
N = number of observation data
x_i = processing time on the i-th observation (seconds)

If N' ≤ N, then the number of observational data is adequate. N' > N, then the amount of observation data is inadequate, so data collection needs to be done again.

Cycle Time

Cycle time is the time needed to complete one unit of production from raw materials to finished products. Cycle time is calculated using the following equation (Sutalaksana et al., 2006):

$$W_S = \sum x_i / N \quad (5)$$

where,
W_S = cycle time (seconds)
x_i = production process time at the i-th observation (seconds)
N = number of observations made

Normal Time

Normal time is the time of the production process by considering the adjustment factor, calculated using the following equation (Sutalaksana et al., 2006):

$$Wn = (Ws \times p) \quad (6)$$

where,
Wn = normal time (seconds)
Ws= cycle time (seconds)
P = Westinghouse method adjustment factor

Standard Time

Standard time is the time taken by the operator to produce one unit of product. The standard time for each production process must take into account the tolerance for rest and unavoidable factors. Standard time is calculated using the following equation (Sutalaksana et al., 2006):

$$Wb = Wn\,(1 + i) \quad (7)$$

Where,
Wb = standard time (seconds)
Wn = normal time (seconds)
I = allowance

Material Handling Cost (MHC)

Factors that affect the calculation of material handling costs are the distance from one production process to another. The distance measurement is adjusted to the existing conditions. If the distance (path length) is known and the frequency of material transfer has been calculated, then the MHC value can be determined by the following equation (Sutalaksana et al., 2006):

MHC per meter = MHC per month / total distance (8)

so,
MHC total = MHC per meter x distance x frequency (9)

RESULTS AND DISCUSSION

Initial Condition of Production Facility Layout

The initial layout of the production facilities condition at CV Mumtaz Bakery is shown in Figure 1. The bread production process at CV Mumtaz Bakery generally includes raw materials preparation, raw materials mixing, stirring, dough distribution, dough molding and dough forming, fermentation, baking, cooling, peeling, packing, and storage. The raw materials prepared include wheat flour, sugar, margarine, calcium, yeast, softener, salt, and butter. The raw materials are taken from the raw material storage area to be prepared and mixed at the mixing workstation. Raw materials mixing is then carried out according to the ingredients composition of the bread produced.

The mixed material is then brought to the mixing workstation. Stirring is done using a mixer for 10 minutes to mix all the ingredients until the desired texture is obtained. The mixed dough is then transferred to be divided according to the specified weight at the distribution workstation. The weight of the dough for each batch is 3.9 kg. The divided dough is brought to the dough press to be molded or shaped according to the type of bread produced and then taken to the fermentation room. Fermentation is carried out for 60 minutes to get the desired volume of bread.

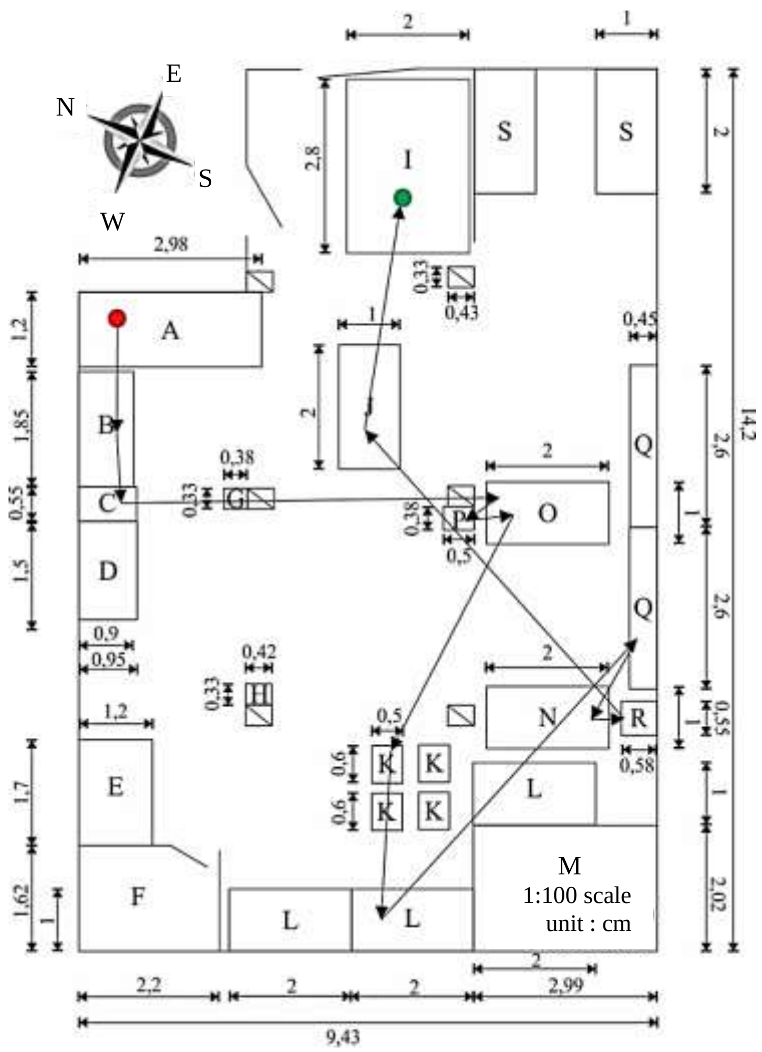
After the fermentation process, the bread dough is baked for 60 minutes at 200 °C in the baking room. The baked bread was then taken to a cooler and cooled for 24 hours to facilitate the following process. In the production of peeled white bread, the bread crust is then peeled at the peeler room. The peeled white bread is then taken to the cutting site to be cut using a cutting machine into ten slices of peeled white bread. The bread is packaged in oriented polystyrene (OPP) plastic in the packing area and then temporarily stored in a storage area before the distribution process.

Production Facility Area

Determination of the area requirement for production facilities is carried out using equation (2) and (3). Table 1 shows the results of all production facilities area calculation at CV Mumtaz Bakery.

Distance Between Production Facilities

The total distance between production facilities for each batch at CV Mumtaz Bakery is 37.15 m. Table 2 shows the distance between production facilities. If the production at CV Mumtaz Bakery per day is assumed to be an average of 10 batches, with 24 working days per month, then the total distance between production facilities per year is 106,992 m. According to Faishol et al. (2013), the industry in general experiences many obstacles regarding inefficient material transfer distance. One example is a production process with cross-movements caused by an irregular machine layout. Irregular machine layouts and long distances between production rooms can cause a disrupted production process, slowing down the production process.



where,
●: Start of production process
●: End of production process
A: raw material room; B: material mixing room; C: stirring room; D: pan storage room; E: equipment washing room; F: toilets; G: topping making room; H: stirring room; I: storage room; J: packing room; K: fermentation room; L: baking room; M: stairs; N: peeling room; O: dough dividing room; Q: dough molding room; Q: cooling room; R: cutting room; S: equipment storage room.

Figure 1. Initial Layout of Production Facilities at CV Mumtaz Bakery

Table 1. Calculation of the bread production facility area

Workstations	Length (m)	Width (m)	Machine Area (m^2)	Production Facility Area (m^2)
Raw material	2.98	1.20	7.27	10.91
Material mixing	1.85	0.90	3.05	4.57
Stirring	0.55	0.95	0.93	1.40
Dough dividing	2.00	1.00	8.75	13.12
Dough molding or dough forming	0.50	0.38	2.26	3.39
Fermenting	0.50	0.60	4.20	25.20
Baking	2.00	1.00	3.50	15.75
Cooling	2.60	0.45	3.12	9.36
Peeling	2.00	1.00	8.75	13.12
Cutting	0.55	0.58	0.73	1.09
Packing	2.00	1.00	8.75	13.12
Storage	2.80	2.00	15.05	22.57
Total			66.36	133.60

Table 2. Total distance between production facilities in the initial layout at CV Mumtaz Bakery

Workstations	Distance Between Workstations (m)
Raw material- Material mixing	1.50
Material mixing - Stirring	0.20
Stirring - Dough dividing	6.20
Dough dividing- Dough molding or dough forming	1.00
Dough molding or dough forming- Fermenting	4.60
Fermenting - Baking	1.10
Baking - Cooling	8.80
Cooling - Peeling	2.40
Peeling - Cutting	0.45
Cutting - Packing	7.30
Packing - Storage	3.60
Total	37.15

Table 3. Time of material transfer in the initial layout of production facilities at CV Mumtaz Bakery

Workstations	Transfer Time (seconds)
Raw material- Material mixing	1
Material mixing - Stirring	1
Stirring - Dough dividing	4
Dough dividing- Dough molding or dough forming	2
Dough molding or dough forming- Fermenting	3
Fermenting - Baking	1
Baking - Cooling	6
Cooling - Peeling	2
Peeling - Cutting	1
Cutting - Packing	5
Packing - Storage	2
Total	28

Material Transfer Time on Initial Layout of Production Facilities

Table 3 shows the material transfer duration at CV Mumtaz Bakery production facility initial layout. The calculation done with the assumption of 28 seconds transfer duration per batch, 10 times production per day and 24 working days per month. The result of material transfer duration is 22.40 hours per year.

Data Adequacy Test

A data adequacy test is used to determine the data amount is adequate enough to be analyzed. The data taken is still inadequate when conducting 13 observations at the dough molding or dough forming workstation, so additional observations are needed. The results of calculating the data adequacy at the dough molding or dough forming workstation have been fulfilled after 14 observations were made, which is indicated by a data adequacy value of 13.70 (Table 4). According to Nurhasanah et al. (2014) the data adequacy test is used as validation that the taken data is sufficient for analysis.

Cycle Time, Normal Time and Standard Time

Cycle time is the time required to produce one finished product from raw materials. The calculation results of cycle time, normal time, and standard time of CV Mumtaz Bakery bread production process using the equation (5), (6), and (7) are respectively 23.81 hours, 24.04 hours, and 30.54 hours. According to Nurhasanah et al. (2014), the purpose of calculating normal time is to normalize working time due to changes in operator performance. The abnormality is caused by the operator working too fast or too slow than the normal state. Slack is the time required for a trained worker to achieve actual performance if the worker is working normally. A worker can't work all day long without interruptions for certain human needs (Rachman, 2013). The calculation of standard time must consider the allowance factor.

Initial Layout Material Handling Cost

Material handling costs in the production process are calculated according to the production facilities initial layout at CV Mumtaz Bakery, which has a total distance 37.15 m between production facilities. The calculation result of initial layout material handling cost is IDR 490.38 per batch make it IDR 1,412,294.00 per year (assuming 10 batches of production per day with 24 working days per month).

Table 4. Calculation of data adequacy test

Workstations	N	N’	Description
Raw material	14	9.40	Adequate
Material mixing	14	9.40	Adequate
Stirring	14	4.02	Adequate
Dough dividing	14	5.90	Adequate
Dough molding or dough forming	14	13.70	Adequate
Fermenting	14	4.50	Adequate
Baking	14	2.03	Adequate
Cooling	14	7.70	Adequate
Peeling	14	6.70	Adequate
Cutting	14	5.50	Adequate
Packing	14	6.30	Adequate
Storage	14	10.08	Adequate

N = the number of observations made, N' = production time calculation result

If N' ≤ N, then the amount of data is adequate, If N' > N, then the amount of data is inadequate

Table 5. Activity relationship chart matrix

No	Workstations	Area Code	A	B	C	O	P	K	L	Q	N	R	J	I
			1	2	3	4	5	6	7	8	9	10	11	12
1	Raw material	A	-	A	E	I	O	U	U	U	U	U	U	X
2	Material mixing	B	-	-	A	E	O	O	U	U	U	U	U	X
3	Stirring	C	-	-	-	A	I	O	U	U	U	U	U	X
4	Dough dividing	O	-	-	-	-	A	I	U	U	U	U	U	X
5	Dough molding or dough forming	P	-	-	-	-	-	A	O	U	U	U	U	X
6	Fermenting	K	-	-	-	-	-	-	A	I	U	U	U	X
7	Baking	L	-	-	-	-	-	-	-	A	O	O	O	U
8	Cooling	Q	-	-	-	-	-	-	-	-	A	I	O	U
9	Peeling	N	-	-	-	-	-	-	-	-	-	A	I	U
10	Cutting	R	-	-	-	-	-	-	-	-	-	-	A	I
11	Packing	J	-	-	-	-	-	-	-	-	-	-	-	A
12	Storage	I	-	-	-	-	-	-	-	-	-	-	-	-

where,
A = absolutely necessary closeness
E = especially very important closeness
I = important closeness
O = ordinary closeness
U = unnecessary closeness
X = avoid closeness

Alternative Production Facility Layout

The alternative layout of facilities using the BLOCPLAN algorithm is obtained with input based on the degree of relationship between the production processes. Table 5 shows the relationship degree determination using qualitative analysis of the Activity Relationship Chart (ARC). The ARC data on BLOCPLAN becomes the consideration of the algorithm in generating 20 alternative production facilities layouts, as shown in Table 6. Alternative production facilities layouts were then selected based on the highest R-score value, which is 0.86. The R-score is a normalized relationship distance score which indicates that the recommended production facilities layout will be optimal if the score is close to 1.

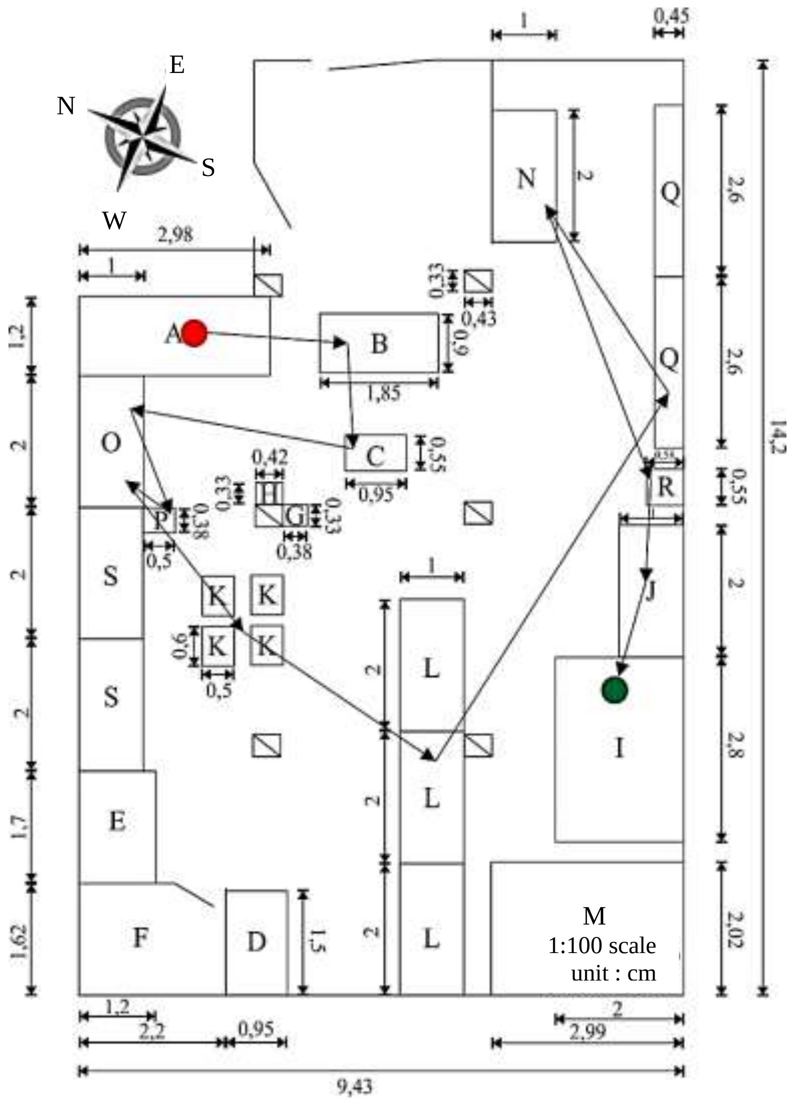
BLOCPLAN displays the coordinates (centroids) along with the length and width measurements for each production facility. Table 7 shows the coordinate points along with the length and width of each production facility on the best alternative layout of production facilities. The data centroids given are not fully following the actual area of space. Adjustments are then made using CorelDraw software to get a more in line actual space area of production facility layout. Figure 2 shows the layout of production facilities based on data centroids generated by the BPLAN90 software.

Table 6. Data processing results through the BLOCPLAN algorithm

Layout	Adjacent Score	R-Score	Relationship Distance Score	Material movement
1	0.73-13	0.72-15	176-15	0-1
2	**0.78-8**	**0.86-1**	**-88-1**	**0-1**
3	0.78-8	0.83-3	-54-2	0-1
4	0.78-8	0.73-13	163-13	0-1
5	0.79-6	0.77-10	90-10	0-1
6	0.73-13	0.79-7	28-7	0-1
7	0.82-3	0.78-9	50-8	0-1
8	0.72-16	0.75-12	117-11	0-1
9	0.69-18	0.64-20	381-20	0-1
10	0.79-6	0.78-8	69-9	0-1
11	0.84-2	0.80-6	2-5	0-1
12	0.78-11	0.81-4	6-6	0-1
13	0.80-5	0.71-16	170-14	0-1
14	0.73-15	0.66-18	301-18	0-1
15	0.82-3	0.84-2	-20-3	0-1
16	0.76-12	0.76-11	140-12	0-1
17	0.71-17	0.70-17	248-17	0-1
18	0.86-1	0.80-5	-4-4	0-1
19	0.60-20	0.64-19	344-19	0-1
20	0.69-18	0.72-14	183-16	0-1

Table 7. The production facility coordinates as a result of data processing using the BLOCPLAN algorithm on the selected layout

Workstations	Centroids		Length (L)	Width (W)	L/W
	X	Y			
A	12.20	7.84	2.9	3.8	0.8
B	12.09	5.13	3.1	1.6	1.9
C	10.23	5.13	0.6	1.6	0.4
O	9.05	7.84	3.4	3.8	0.9
P	6.95	7.84	0.8	3.8	0.2
K	3.28	7.84	6.6	3.8	1.7
L	4.96	5.13	9.9	1.6	6.2
Q	9.60	2.16	2.1	4.3	0.5
N	12.14	2.16	3.0	4.3	0.7
R	8.44	2.16	0.2	4.3	0.1
J	6.82	2.16	3.0	4.3	0.7
I	2.66	2.16	5.3	4.3	1.2



where,
: Start of production process
: End of production process
A: raw material room; B: material mixing room; C: stirring room; D: pan storage room; E: equipment washing room; F: toilets; G: topping making room; H: stirring room; I: storage room; J: packing room; K: fermentation room; L: baking room; M: stairs; N: peeling room; O: dough dividing room; Q: dough molding room; Q: cooling room; R: cutting room; S: equipment storage room.

Figure 2. Production Facility Layout Alternative Design for CV Mumtaz Bakery

Table 8. Distance between production facilities in alternative layout

Workstations	Distance Between Workstations (m)
Raw material- Material mixing	2.35
Material mixing - Stirring	0.75
Stirring - Dough dividing	3.40
Dough dividing- Dough molding or dough forming	1.80
Dough molding or dough forming- Fermenting	2.70
Fermenting - Baking	2.60
Baking - Cooling	9.00
Cooling - Peeling	1.70
Peeling - Cutting	4.80
Cutting - Packing	0.80
Packing - Storage	1.80
Total	31.70

Table 9. Material transfer times on alternative layouts

Workstations	Transfer Time (seconds)
Raw material- Material mixing	2
Material mixing - Stirring	1
Stirring - Dough dividing	2
Dough dividing- Dough molding or dough forming	2
Dough molding or dough forming- Fermenting	2
Fermenting - Baking	2
Baking - Cooling	6
Cooling - Peeling	2
Peeling - Cutting	3
Cutting - Packing	1
Packing - Storage	2
Total	25

Distance between Alternative Layout Production Facilities

Table 8 shows the distance between production facilities in the alternative layout. The total distance between production facilities in the alternative layout is 31.70 m per batch. If the production volume of CV Mumtaz Bakery per day is assumed to be an average of 10 batches with 24 working days per month, then the total distance between production facilities is 91,296 m per year. The alternative layout has a shorter material transfer distance compared to the initial layout.

Alternative Layout Material Transfer Time

The transfer time on the selected production facility layout is 25 seconds per batch. If the total production of CV Mumtaz Bakery per day is assumed to be an average of 10 batches with 24 working days per month, then the material transfer time is 20.00 hours per year. The material transfer time in the alternative layout is shown in Table 9. The alternative layout has a shorter material transfer time compared to the initial layout.

Material Handling Cost of Alternative Layout

Material handling costs at production facilities using an alternative layout with a total distance between production facilities of 31.70 m is IDR 434.29 per batch. If the total production at CV Mumtaz Bakery per day is assumed to be an average of ten batches with 24 working days per month, then the total material handling costs for the production facility layout is IDR 1,250,755.00 per year.

CONCLUSIONS

The analysis of production facilities layout at CV Mumtaz Bakery using the BLOCPLAN algorithm resulting the best layout of production facilities with a total distance of 91,296 m between production facilities, 20 hours of transfer time, and IDR 1,250,755.00 per year of material handling costs. The selected production facility layout is generated under the assumptions of average production of ten batches per day and 24 working days per month. This alternative can reduce the total material transfer distance by 14.67% and can reduce the material transfer time by 10.7% compared to the initial layout. The future possible study related to this research can be conducted on the technical and financial feasibility of the selected layout implementation.

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