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Redesign of Facility Layout and Material Handling in A Cake Production Factory Using Systematic Layout Planning

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Abstract

Every company, including the food and beverage industry shares the same goal, to increase productivity in operational activities. Productivity enhancement is a key factor indicating a company's development. The layout of production facilities plays an important role in improving a company's efficiency to ensure smooth production processes. This research evaluates a cake production factory facility layout and material handling, focusing on challenges from the significant distances between stations. Problems were identified through direct observation and interviews with the factory manager. Employing the Systematic Layout Planning method with ARC and dimensionless diagrams, an analysis was conducted to propose an optimized layout and material handling. The proposed improvements, derived from a keen analysis of workflow sequences and resource allocation, have been validated to substantially decrease the distance of material flow, thereby leading to reduced handling cost and enhancing overall productivity.

Keywords
Cake Production, Facility Layout, Systematic Layout Planning, Optimization and Material Handling.

1. Introduction

Productivity enhancement is a key factor indicating a company's development (Wahyuni and Setiawan, 2017). Productivity is generally defined as the ratio of output to input (Nasution, 2007). The arrangement of production layout is a factor that affects productivity (Sutrisno, 2017). The layout of production facilities plays an important role in improving a company's efficiency to ensure smooth production processes. According to Apple (1990), layout involves arranging plant facilities to support the production process. This arrangement utilizes space for placing machines or other production support facilities, smooth material movement, storage of materials (temporary or permanent), personnel, and more.

One thriving and expanding food industry is the bread industry. The bread industry is rapidly growing and widely known in society, producing bread of various quality levels, from high to low. In Bekasi City, there is a bread industry named D’Cika Cakes & Bakery, which has 18 branches in Bekasi, Jakarta, and Depok. D’Cika Cakes & Bakery produces various products daily, such as plain bread and sweet bread. D’Cika & Bakery is facing several issues with its production facility layout, such as long distances between workstations, varied functions at each station leading to backtracking, and the lack of clear markers between stations, often obstructing workflow. These issues can disrupt operator movement and increase musculoskeletal complaints due to the suboptimal space for movement at each workstation.

1.1 Objectives
The objectives of designing the facility layout at the D’Cika Cakes & Bakery production factory is to create a more effective, efficient, and economical workplace. This redesign aims to increase work productivity, reduce production waiting time (delays), optimize facility placement, and minimize factors that negatively impact the quality of raw materials and finished products.

2. Literature Review
2.1 Facility Layout Planning
According to Hadiguna (2008), facility layout can be defined as a collection of physical elements arranged according to certain rules or logic. Facility layout is a part of facility design that focuses on arranging these physical elements, which can include machines, equipment, tables, buildings, etc. A good production facility layout is characterized by the absence of backtracking, minimum frequency of movement, no excessive queuing (bottlenecks), and enhanced effectiveness and efficiency through reduced material movement distance and lower material handling costs (Setiyawan et al., 2017).

2.2 Systematic Layout Planning
The SLP method is effective in resolving issues related to production flow, transportation, warehousing, and other activities (Purnomo, 2004). It is chosen for its suitability to the characteristics of companies that require adjustments in organizing facilities on the production floor. According to Tamimi Z et al. (2018), SLP is an appropriate method for designing efficient layouts as it accurately considers the value of relationships and material flow.

2.3 Material Handling Cost
According to Buchari (2018), in the production process, sometimes the flow of materials is unbalanced. This imbalance in production is caused by differences in cycle times at each workstation. Additionally, other issues include irregular material flow patterns leading to increased time and distance for movement. High material handling costs can result in inefficiency in a company's productivity (I F Febriandini and Yuniaristanto, 2019). Factors affecting material handling cost calculations include the distance from one workstation to another and the transportation cost per meter of movement. According to Syed A A N., et al. (2016), alternative layouts can be proposed based on criteria such as improved accessibility and efficiency of material flow. Dede M (2018) suggests that one method for measuring distances is the Euclidean Distance method. Euclidean Distance is the straight-line distance measured between the centers of two facilities.

3. Methods
The method that has been done in this research can be seen in the flowchart in Figure 1.

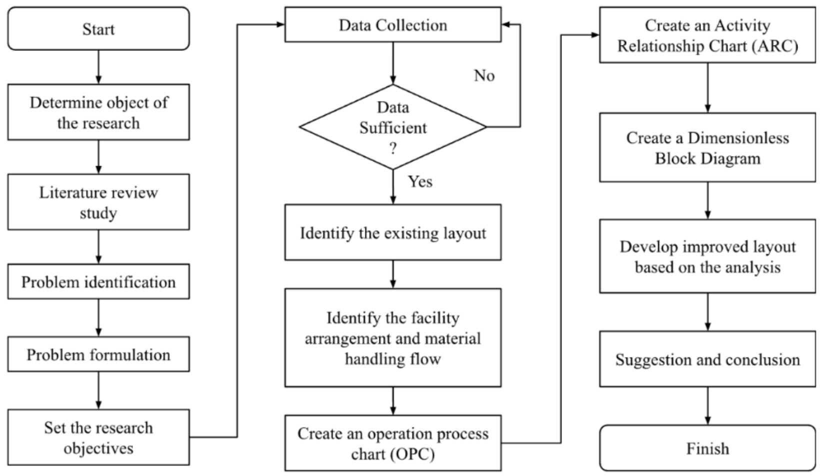


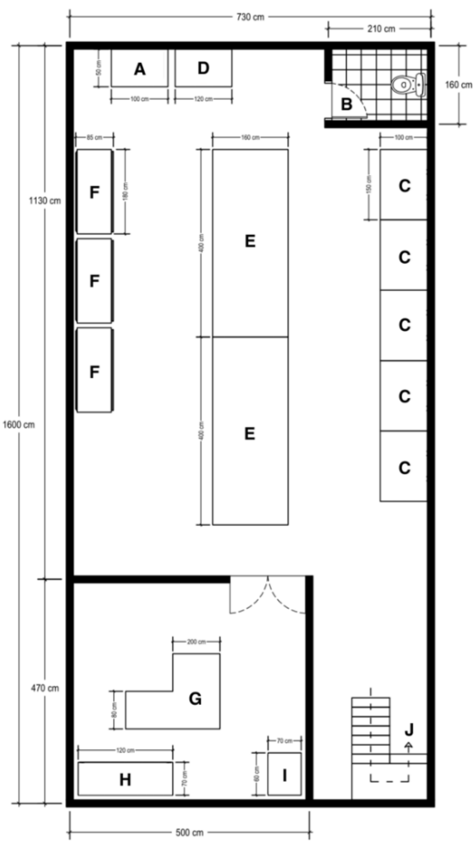
Figure 1. Methodology flow

4. Data Collection

4.1 Existing Layout

After conducting direct observations, we analyzed the layout and configuration of the cake production factory. Figure 2 shows the existing layout of the factory, consisting of production area and assembly area. The flow of material handling begins from the production area on the 4th floor, moves to the assembly area on the 1st floor, and is then placed into the display area of the bakery store.

a)



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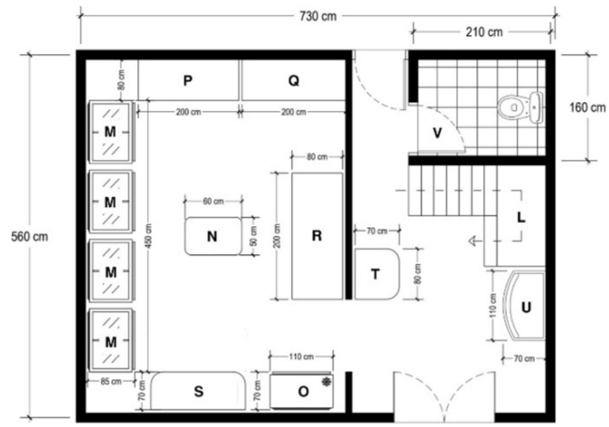


Production Area		Assembly Area	
A	Sink	L	Stairs
B	Restroom (WC)	M	Freezer
C	Mixing Station	N	Chilling Station
D	Stove	O	Production Room Chiller
E	Multifunction Station	P	Filling Station
F	Oven	Q	Coating Station
G	Packing Station	R	Shaping & Packaging Station
H	Storage Shelf 1	S	Finishing Station
I	Storage Shelf 2	T	Additional Decoration Table
J	Stairs	U	Display Chiller
		V	Restroom (WC)

Figure 2. Existing layout of a) production and b) assembly area

4.2 Number of Machines

An integral component of this layout is the machinery. The quantity and capabilities of these machines, crucial for the factory's optimal performance, directly influence not just the production capacity but also the operational flow and spatial arrangement of the manufacturing floor. As shown in Table 1.

4.3 Number of Operators

The workforce, particularly the number of operators, is another critical aspect. Operators are responsible for managing the machinery and ensuring the continuity of production processes. The number of operators must be sufficient to handle the workload without leading to excessive fatigue or idle time. Table 1 shows the number of machines and number of operators in the cake production factory.

Table 1. Number of machines and operators in the cake production.

Number of Machines		Number of Operators	
Assembly Area Digital Mixer	2	Production Area	5
Chocolate Mixing Machine	2		
Freezer	4		
Oven	8	Assembly Area	5
Production Area Digital Mixer	5		
Stove	1		

4.4 Operation Process Chart

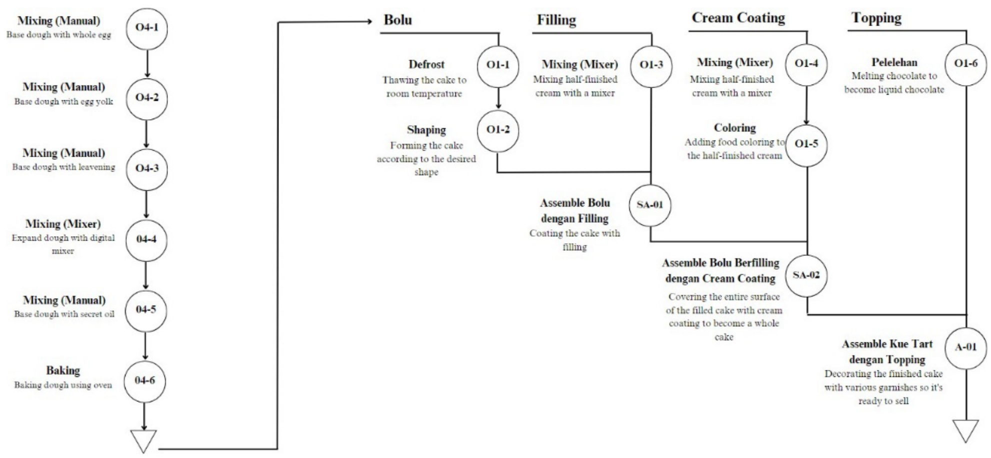


Figure 3. Operation process chart

An operation process chart is a graphical representation of the sequence and interaction of processes within the manufacturing setup. Figure 3 depicts the Operation Process Chart of a cake in the production process. It highlights the flow of materials and the transition of components through various stages of the manufacturing process.

4.5 Time Standard

Furthermore, time standards are established to define the optimal time required for a process to be completed. These standards are vital for scheduling, determining labor requirements, and evaluating productivity. They also serve as benchmarks for continuous improvement initiatives within the facility. We also calculate the time standard for every process in both production area and assembly area. (see Table 2 and Table 3.)

Table 2. Time standard for production area

Production Area							
Process	Process Name	Cycle Time	Westinghouse Rate	Normal Time	Allowance	Standard Time	Efficiency
O4-1	Manual mixing	1.4 min	1.11	1.554 min	15%	1.7871 min	85%
O4-2	Manual mixing	0.33 min	1.11	0.3663 min	15%	0.421245 min	85%
O4-3	Manual mixing	0.17 min	1.11	0.1887 min	15%	0.217005 min	85%
O4-4	Mixing (Mixer)	6.3 min	1.11	6.993 min	15%	8.04195 min	85%
O4-5	Manual mixing	0.33 min	1.11	0.3663 min	15%	0.421245 min	85%

O4-6	Baking	20 min	1.11	22.2 min	15%	25.53 min	85%

Table 3. Time standard for assembly area

Assembly Area							
Process	Process Name	Cycle Time	Westinghouse Rate	Normal Time	Allowance	Standard Time	Efficiency
O1-1	Defrost	9.5 min	1.11	10.545 min	15%	12.12675 min	85%
O1-2	Shaping	1.8 min	1.11	19.98 min	15%	22.977 min	85%
O1-3	Mixing for filling	5 min	1.11	5.55 min	15%	6.3825 min	85%
SA-01	Ass. Sponge + Filling	2.4 min	1.11	2.664 min	15%	3.0636 min	85%
O1-4	Mixing for coating	6 min	1.11	6.66 min	15%	7.659 min	85%
O1-5	Coloring	1.2 min	1.11	1.332 min	15%	1.5318 min	85%
SA-02	Ass. Sponge + Coat	3.8 min	1.11	4.218 min	15%	4.8507 min	85%
O1-6	Melting	15 min	1.11	16.65 min	15%	19.1475 min	85%
A-01	Assemble Cake with Topping	8.6 min	1.11	9.546 min	15%	10.9779 min	85%

4.6 Number of Machines Required

Building upon these insights, this section focuses on determining the optimal number of machines needed for efficient operation in a bakery factory. It considers the types of machines such as ovens, mixers, chocolate melting machines, freezers, and stoves, along with their respective quantities required for different floors of the factory. The aim is to ensure that the machinery is adequate to meet production demands without unnecessary redundancy. Based on the data, we propose several recommendations for the optimal quantity of machines, taking account their utility of every machines (see Table 4.)

Table 4. Numbers of Machines Required

Criteria	Oven	Stove	Digital Mixer (Prod. Area)	Digital Mixer (Ass. Area)	Choco Machine
Demand	300 sponge	Oil for 300 sponge	300 sponge	Cream for 100 cake	Choco for 100 cake
One Round Capacity	18 sponge	Oil for 10 sponge	4 sponge	Cream for 9 tart	Cream for 10 tart
Frequency Needed	17 times	30 times	75 times	12 times	10 times
Standard Time	25.53 min	10 min	8.04195 min	14.0415 min	10.9779 min
Downtime	90 min	90 min	60 min	30 min	30 min
Time before Performance	390 min	390 min	420 min	450 min	450 min
Performance Rate	85%	75%	80%	80%	75%
Time with Performance	331.5 min	292.5 min	336 min	360 min	337.5 min
min per Round	19.5 min	9.75 min	4.48 min	40 min	33.75 min
Needed Machine	2 machines	2 machines	2 machines	1 machine	1 machine
Existing Machine	8 machines	1 machine	5 machine	2 machine	1 machine
Recommendation	Eliminate 6	Add 1 machine	Eliminate 3	Eliminate 1	No changes

	machines		machines	machine	needed

4.7 Number of People Required

This section outlines the human resource requirements for the bakery factory, specifying the number of employees needed for different roles and floors. The goal is to maintain a balance between workforce size and productivity, ensuring that each task is adequately staffed for optimal operation. To calculate the total number of employees, we first determine the standard time for each process based on the average demand of 100 cakes per day (see Table 5.) Subsequently, we calculate the number of employees using an 85% performance rate (see Table 6.)

Table 5. Standard time per 100 cake

Process	Standard Time	Standard time per 100 (min)	Standard Time per 100 (hour)	Process	Standard Time	Standard time per 100 (min)	Standard Time per 100 (hour)
O4-1	1.7871	134.0325	2.233875	O1-3	6.3825	38.295	0.63825
O4-2	0.4212	31.59	0.5265	O1-4	7.659	45.954	0.7659
O4-3	0.2171	16.2825	0.271375	O1-5	1.5318	9.1908	0.15318
O4-4	8.0412	603.09	10.0515	O1-6	19.1475	191.475	3.19125
O4-5	0.4212	31.59	0.5265	SA-1	3.0636	306.36	5.106
O4-6	25.53	459.54	7.659	SA-2	4.8507	485.07	8.0845
O1-1	12.1268	72.7608	1.21268	A-1	10.9779	109.779	1.82965
O1-2	2.2977	68.931	1.14885				

	Standard Time	Standard time per 100 (min)	Standard time per 100 (hour)
Total	104.4553	2603.9406	43.39901

Table 6. Total Number of Employees

Total Standard Time	Performance Rate	Total Standard Time	Performance Rate
43.39901 hours	100%	51.05765882 hours	85%

Total Number of Employees	Number of Employees in in Assembly Area	Number of Employees Production Area
51.05765882/8 = 7 people	3 people	4 people

5. Results and Discussion

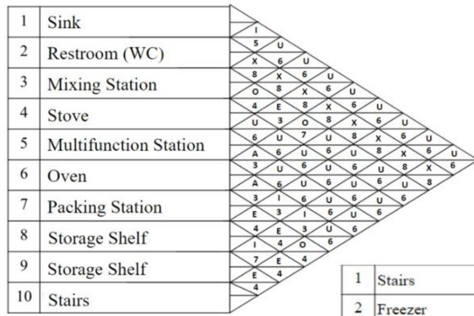
5.1 Activity Relationship Chart

Activity Relationship Chart shows the relationship of every department, office, or service area with every other department and area. Below in Figure 4 is the Activity Relationship Chart (ARC) of the production stations as the main method to generate recommendations by closeness between activities and its resources, and Figure 6 shows the code for the ARC. It aids in planning an efficient and optimal factory layout. Based on the result of ARC in the assembly area, the filling station, coating station, and shaping & packaging station is the main station that is absolutely necessary to be located close to each other. Based on the result of ARC in the production area, the oven is a main station that is absolutely necessary adjacent to the multifunction station and packing station.

Closeness Rating	Description
A	Absolutely necessary that these two departments be next to each other
E	Especially Important
I	Important
O	Ordinary Importance
U	Unimportant
X	Closeness Undesirable

Reason Code	Description
1	Information Flow
2	Degree of Supervision
3	Sequence of Workflow
4	Material Flow
5	Mutual Support Function
6	Unrelated
7	Interconnected Facilities
8	Noise, Dirt, Dust
9	Safety

a)



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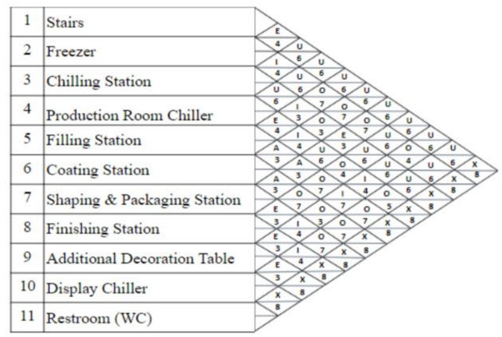

Figure 4. ARC of a) production area and b) assembly area

5.2 Dimensionless Block Diagram

Guided by the ARC, we then delved into the Dimensionless Block Diagram. Dimensionless Block Diagram is a relationship diagram that connect tasks (department or work station) by closeness ratings which consist of "A, E, I, O, U, and X" code from the Activity Relationship Chart (ARC). The analysis of the dimensionless diagram in Figure 5 would be the basis for determining the recommendation layout so it is expected to reduce handling fee.

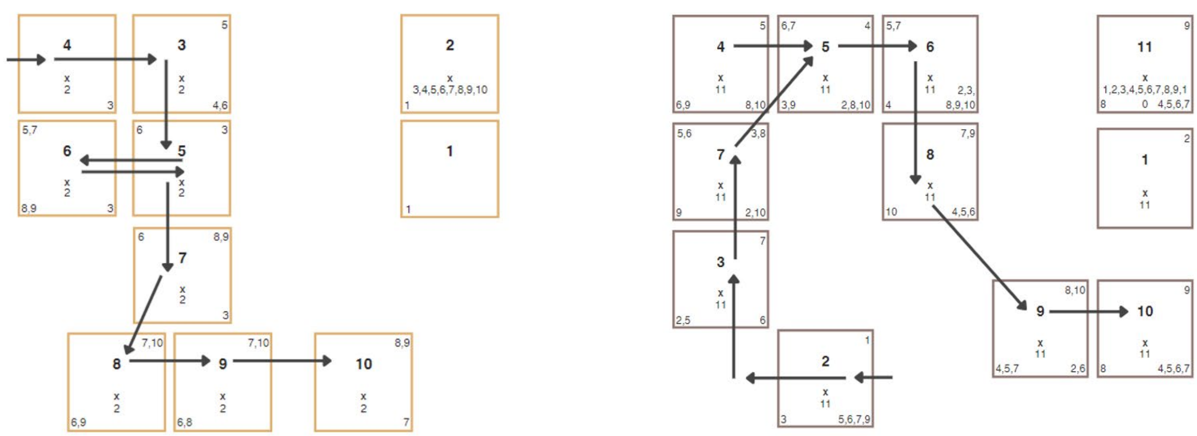

Figure 5. Dimensionless block diagram for a) production area and b) assembly area

5.3 Proposed Improvements

Addressing the core of the problem, the proposed solution is to focus on increasing the bakery productivity by redesigning the bakery layout and improving the sequence of workflow. Figure 6 shows the redesigned layout of the D'Cika Bakery layout. The proposed design of the bakery includes the following list:

1. Redesign Assembly Area by moving the freezer, chilling station, shaping & packaging station, production room chiller, and finishing station based on the Activity Relationship Diagram which is based on sequence of workflow, resources needed, and material flow.
2. Redesign Production Area by moving the mixing station based on the Activity Relationship Diagram which is based on the sequence of workflow, material flow, and the hygiene factors.

These changes are expected to significantly improve the overall efficiency of the Cake Production. Figure presents the redesigned layout of the D'Cika Bakery, illustrating the strategic placement of each section within the cake production to maximize productivity while upholding high standards of hygiene and quality.

Production Area		Assembly Area	
A	Sink	L	Stairs
B	Restroom (WC)	M	Freezer
C	Mixing Station	N	Chilling Station
D	Stove	O	Production Room Chiller
E	Multifunction Station	P	Filling Station
F	Oven	Q	Coating Station
G	Packing Station	R	Shaping & Packaging Station
H	Storage Shelf 1	S	Finishing Station
I	Storage Shelf 2	T	Additional Decoration Table
J	Stairs	U	Display Chiller
		V	Restroom (WC)

Figure 6. Proposed layout of a) production and b) assembly area

5.4 Validation

The proposed redesign is then analyzed for its impact by examining the distance of material flow before and after the redesign. From Table 7, it is evident that the distances between areas before and after improvement significantly decreased, indicating that the recommended layout changes can reduce the distances between workstations, ultimately leading to a reduction in material handling fees.

Table 7. Area-to-area distance in assembly area (in cm2)

Area-to-Area Distance (Assembly Area)				Area-to-Area Distance (Production Area)			
No.	Displacement	Distance Between Areas Before Improvement	Distance Between Areas After Improvement	No.	Displacement	Distance Between Areas Before Improvement	Distance Between Areas After Improvement
1	Stairs - Freezer	565	220	1	Sink - Restroom (WC)	525	160

2	Freezer - Chilling Station	100	107	2	Restroom (WC) - Mixing station	655	325
3	Chilling Station - Production Room Chiller	250	120	3	Mixing Station - Stove	630	310
4	Production Room Chiller - Filling Station	572	90	4	Stove - Multifunction Station	825	590
5	Filling Station - Coating Station	200	200	5	Multifunction Station - Oven	223	305
6	Coating Station - Shaping & Packaging Station	220	250	6	Oven - Packing station	765	630
7	Shaping & Packaging Station - Finishing Station	75	250	7	Packing Station - Storage Shelf 1	135	135
8	Finishing Station - Additional Decoration Table	250	130	8	Storage Shelf 1 - Storage Shelf 2	405	405
9	Additional Decoration Table - Display Chiller	150	150	9	Storage Shelf 2 - Stairs	440	440
10	Display Chiller - Restroom (WC)	290	290				
	Total	**2672**	**1807**		**Total**	**4603**	**3300**

Table 8. OMH calculation

Calculating the Wage					
	Per Day	**Per Hour**	**Per Minute**	**Per Second**	**Per TMU**
Wage	IDR 243,000	IDR 30,375	IDR 506.25	IDR 8.44	IDR 0.304
Calculating the OMH (Operational Material Handling) Cost per Meter					
Using the MOST method, where 3-4 steps (1 meter) are categorized in index A6 with a number index of 6 TMU					
OMH per Meter: IDR 0.304 per TMU x 6 TMU = IDR 1.82 per meter					

From Table 8., with a new daily wage of IDR243,000 and an 8-hour shift, the OMH per meter is calculated to be approximately IDR1.82. Calculation of the moment of movement is an important metric that quantifies motion within the assembly area and production area and provides a basis for measuring improvements. This section presents a detailed before-and-after comparison showing the impact of layout optimization on the frequency and distance of movements between different stations within an assembly area. The OMH for production area before improvement was IDR 761,511.11 and for the assembly area was IDR 645,811.71. Table 9. and Table 10. shows the after improvement for the production area and assembly area.

Table 9. OMH cost calculation after improvement for production area

Moment of Movement Calculation After Improvement for Production Area							
No.	**Movement**	**Distance Between Areas After Improvement (m)**	**Frequency**	**Moment of Movement (m)**	**OMH/ meter/day (IDR)**	**Total OMH/day After Improvement (IDR)**	**Total OMH/mo After Improvement (IDR)**
1	Sink – Restroom (WC)	5.25	-	0.00	IDR 1.82	IDR 0.00	IDR 0.00
2	Restroom (WC) – Mixing Room	6.55	-	0.00	IDR 1.82	IDR 0.00	IDR 0.00
3	Mixing Station – Stove	6.30	75.00	472.50	IDR 1.82	IDR 423.15	IDR 12,694.50
4	Stove – Multifunction Station	8.25	75.00	618.7	IDR 1.82	IDR 805.35	IDR 24,10.50

				5			
5	Multifunction Station – Oven	2.23	36.00	80.28	IDR 1.82	IDR 199.84	IDR 5,995.08
6	Oven – Packing Station	7.65	75.00	572.75	IDR 1.82	IDR 859.95	IDR 25,789.50
7	Packing Station – Storage Shelf 1	1.35	38.00	51.30	IDR 1.82	IDR 93.37	IDR 2,800.98
8	Storage Shelf 1 – Storage Shelf 2	4.05	-	0.00	IDR 1.82	IDR 0.00	IDR 0.00
9	Storage Shelf 2 - Stairs	4.40	4.00	17.60	IDR 1.82	IDR 32.03	IDR 960.96
Total		46.03	303.00	13,947.09	IDR 1.82	IDR 18,198.18	IDR 545,945.40

Table 10. OMH cost calculation after improvement for assembly area

Moment of Movement Calculation After Improvement for Assembly Area							
No.	**Movement**	**Distance Between Areas After Improvement (m)**	**Frequency**	**Moment of Movement (m)**	**OMH/meter/day (IDR)**	**Total OMH/day After Improvement (IDR)**	**Total OMH/mo After Improvement (IDR)**
1	Stairs – Freezer	2.20	1.00	2,20	IDR 1.82	IDR 4.00	IDR 120.12
2	Freezer – Chilling Station	1.07	16.67	17.83	IDR 1.82	IDR 32.46	IDR 973.70
3	Chilling Station – Production Room Chiller	1.20	25.00	30.00	IDR 1.82	IDR 54.60	IDR 1,638.00
4	Production Room Chiller – Filling Station	0.90	50.00	45.00	IDR 1.82	IDR 81.90	IDR 2,457.00
5	Filling Station – Coating Station	2.00	50.00	100.00	IDR 1.82	IDR 182.00	IDR 5,460.00
6	Coating Station – Shaping & Packaging Station	2.50	50.00	125.00	IDR 1.82	IDR 227.50	IDR 6,825.00
7	Shaping & Packaging Station – Finishing Station	2.50	50.00	125.00	IDR 1.82	IDR 227.50	IDR 6,825.00
8	Finishing Station – Additional Decoration Table	1.30	100.00	130.00	IDR 1.82	IDR 236.60	IDR 7,098.00
9	Additional Decoration Table – Display Chiller	1.50	100.00	130.00	IDR 1.82	IDR 273.00	IDR 8,190.00
10	Display Chiller – Restroom (WC)	2.50	-	0.00	IDR 1.82	IDR 0.00	IDR 0.00
Total		18.07	442.67	7,998.99	IDR 1.82	IDR 14,558.16	IDR 436,744.67

Based on the post-improvement table, there is a notable reduction in the total distance of movement, which correlates with increased efficiency and reduced Operational Material Handling (OMH) cost. These improvements highlight the importance of meticulous facility design and underscore the potential for significant cost savings and productivity enhancements. The moment of movement and OMH cost calculation serves not only as a measure of current efficiency but also as a guide for continuous improvement in manufacturing facility operations.

6. Conclusion

In conclusion, this research has successfully met all its stated objectives, culminating in a comprehensive redesign of the Cake Production layout to streamline the production process. The innovative use of the Activity Relationship Chart (ARC) and the Dimensionless Block Diagram (DBD) in determining the optimal arrangement of workstations has led to a unique contribution within the field of industrial engineering and operations management. This meticulous approach has ensured that critical stations in both the Assembly and Production Areas are positioned to maximize efficiency and reduce unnecessary movement.

The proposed improvements, derived from a keen analysis of workflow sequences and resource allocation, have been validated to substantially decrease the distance of material flow, thereby leading to reduced handling fees and enhancing overall productivity. The significant reductions in distance between workstations not only affirm the efficacy of the new design but also highlight the novel contribution of this research in optimizing operational layouts. By achieving a perfect blend of theoretical frameworks and practical application, the study sets a precedent for future research in layout optimization. The strategic relocation of the freezer, chilling station, shaping & packaging station, production room chiller, and finishing station—guided by the principles outlined in the Activity Relationship Diagram—reflects a tailored solution addressing the specific needs of the Cake Production. This level of customization in design is indicative of the research's unique contribution to the industry, providing a scalable and adaptable methodology for similar enterprises seeking efficiency enhancements through intelligent design and layout optimization.

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