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FACILITY LAYOUT IMPROVEMENT FOR CONTINUOUS PRODUCTION SYSTEM: A CASE STUDY IN CHOCOLATE-BASED PRODUCT

PERBAIKAN TATA LETAK FASILITAS SISTEM PRODUKSI KONTINU: STUDI KASUS PADA PRODUK COKELAT

Anas Saifurrahman*, Hamzah Fath, Darywan Damar Baasith, Yumna Nur Aini, and Arif Wibisono
Faculty of Engineering, Universitas Gadjah Mada

Sang Norma Lintang Asmara
School of Vocational College, Universitas Gadjah Mada

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ABSTRAK

Penelitian ini mengeksplorasi tata letak fasilitas sistem produksi coklat yang optimal di Yogyakarta, untuk meningkatkan produksi laboratorium hingga skala produksi massal, yaitu pada laboratorium Field Research Center UGM. Tata letak laboratorium dioptimasi berdasarkan penilaian ahli dan algoritma ALDEP kemudian dilakukan perbandingan nilai distance-based objective dengan tata letak saat ini. Kedua tata letak ini dibandingkan untuk melihat pentingnya aspek kualitatif dalam penentuan posisi stasiun kerja selain hanya aspek kuantitatif. Hasil analisis distance-based menunjukkan bahwa tata letak ALDEP mengungguli semua alternatif lainnya, sehingga tata letak berdasarkan algoritma ALDEP memiliki biaya penanganan material terendah, dengan penurunan nilai perpindahan sebesar 23% dibandingkan tata letak saat ini. Meskipun tata letak yang diusulkan berdasarkan penilaian ahli memiliki kinerja yang lebih buruk, tata letak tersebut memenuhi persyaratan pemangku kepentingan seperti keselamatan dan kemudahan observasi. Oleh karena itu, penting bagi penelitian selanjutnya untuk dapat melibatkan aspek lain di luar biaya dalam metrik evaluasi untuk mempertimbangkan tata letak terbaik.

Keywords: *ALDEP; SLP; Perbaikan Tata Letak; Sistem Produksi Cokelat; Distance-Based Objective.*

ABSTRACT

This study explores optimizing Yogyakarta's chocolate production system facility layout to enhance laboratory-scale production to mass production at the UGM Field Research Center laboratory. The laboratory layout was optimized based on expert assessments and the ALDEP algorithm and compared with the current layout using distance-based objective values. Both layouts were compared to highlight the importance of qualitative aspects in determining workstation positions, in addition to quantitative aspects. The distance-based analysis results indicate that the ALDEP layout outperforms the current layout, and the layout was designed with expert assessments, showing the highest efficiency and lowest material handling costs, with an estimated improvement of 23% over the current layout. Although the proposed expert-assessed layout performed worse, it met stakeholder requirements such as safety and ease of observation. Therefore, future research must consider other aspects beyond costs in evaluation metrics to determine the best layout. Although the proposed expert-assessed layout performed

*Corresponding author: anas.s@ugm.ac.id

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Keywords: *ALDEP; SLP; Improvement Layout; Chocolate Production System; Distance-Based Objective.*

INTRODUCTION

Chocolate is a highly sought-after food commodity among Indonesian consumers. According to Katadata (Dihni, 2022), Indonesia ranks 6th in per capita chocolate consumption, with an average consumption of 7.3 kg per person per year. Consequently, this consumption rate has also driven chocolate industry players to increase their production capacity. The Special Region of Yogyakarta (DIY) is one of the potential locations for cocoa production. A local news article (Atmasari, 2019) reported that cocoa farming groups in Kulon Progo collected 80 kilograms of market-ready cocoa beans. The abundance of cocoa raw materials presents significant opportunities for mass production of cocoa-derived products. Many production facilities within the DIY areas are dedicated to transforming cocoa into finished chocolate products.

Efforts to increase mass production of cocoa-derived products have been made in DIY. Some production units have even focused on specific market segments, such as becoming souvenir centers. As benchmarks, "Cokelat Ndalem" and "Cokelat Monggo" are businesses that utilize their chocolate products as souvenirs. These offered products have strong branding, ensuring that buyers perceive them primarily as souvenirs. Additionally, chocolate composition, particularly the combination of flavor components, is paramount. In determining the suitable flavor combination to align with consumer preferences (Ariesi et al., 2019), the Quality Laboratory at the Department of Biological and Veterinary Technology, Vocational School of UGM, is currently establishing configurations for sweetness level, bitterness level, and acidity level to achieve a chocolate flavor that resonates with DIY residents' preferences. Previous research has been done to improve product quality on a laboratory scale. However, scale-up concerns are becoming an essential issue in generating higher opportunities.

Currently, research related to Facility Layout Planning (FLP) generally uses three approaches: heuristic methods, metaheuristic methods, and simulation (Al-Zubaidi et al., 2021). The current trend in FLP-related research is towards using metaheuristic methods, as these methods provide solutions in a relatively short time for complex problems (Besbes et al., 2020). However, metaheuristic methods only provide reasonable solutions using the appropriate algorithm and performing parameter tuning well (Palomo-Romero et al., 2017). Parameterization is required in metaheuristic algorithms, one of which is by using Monte Carlo simulation (Besbes et al., 2020). Unlike determining the distance between workstations using the Manhattan or Euclidean method, which does not consider obstacles, this study finds barriers in determining the distance between workstations. Moreover, the usage of GA is also involved in FLP problems, such as single-row facility layout problems (Maghfiroh, 2021).

Heuristic methods have been widely used in various research on diverse production facilities. Some methods that are commonly used to solve FLP problems are CORELAP and ALDEP. These methods only require a little and can use qualitative data (Saifurrahman & Sudiarso, 2022). However, compared to simulation methods, these methods need to improve their flexibility in generating phenomena of interest from the observed system. Nevertheless, these methods have been widely used in various production facilities and have produced improvements that can be seen in the results due to their easy application and lack of need for diverse data (Rifai et al., 2023).

The use of heuristic methods has been employed in many studies across a variety of production types, such as customized job shops (Mebrat & Haile, 2023; Suhardini & Rahmawati, 2019), waste processing industry (Rifai et al., 2023), rubber industry (Tambunan et al., 2018), and the printing industry (Puspita et al., 2017). In these studies, the number of workstations in the observed production facilities varies from relatively minor (Suhardini & Rahmawati, 2019) to large (Rifai et al., 2023). Generally, there is an improvement in the performance of these production facilities, both in terms of Material Handling Cost (Mebrat & Haile, 2023; Suhardini & Rahmawati, 2019), profit (Puspita et al., 2017), and space utilization (Rifai et al., 2023; Tambunan et al., 2018). The heuristic method is robust and can be used in different industry sizes to produce improvements from the observed metrics.

The planning of facility layout is a crucial aspect to consider in a production facility because the layout will influence the facility's performance, which in turn impacts the profit obtained by the company (Hari Prasad et al., 2014). Layout planning must be carried out, especially in a facility with interconnected workstations (Ojaghi et al., 2015), such as food manufacturing production facilities. Currently, many studies discuss layout planning in the food industry with various approaches (Amit et al., 2012; Ojaghi et al., 2015; Pakdel et al., 2023; Arifin et al., 2022). However, there needs to be research discussing layout planning in chocolate production facilities. Chocolate production is a complex process (Barišić et al., 2019) that requires various processes that require several technological operations and is sensitive to temperature and humidity. In addition, layout planning in the chocolate industry faces some challenges in the context of product contamination prevention and material handling that affect the quality of the product itself (Pakdel et al., 2023). Therefore, this study will discuss layout planning facilities in the chocolate industry. The approach used in the study is ALDEP, which will be discussed further in the methodology.

In order to commercialize chocolate products based on optimal compositions, the Fabrication Laboratory at the Department of Biological and Veterinary Technology (DTHV) at the Vocational School (SV) of UGM possesses operational machinery facilities. This has been done to produce milk chocolate and dark chocolate on a larger scale as a means of support for Sustainable Development Goals (SDGs) related to sustainable development in industry, innovation, and infrastructure. However, the current production floor needs an organized system. The arrangement of machinery configurations still needs to be fixed despite the facilities being ready for operation. Although facility planning requires time to achieve optimal decisions, its implications for operational smoothness are significant (Al-Zubaidi et al., 2021).

Meanwhile, the chocolate-making process at each workstation has yet to be further investigated regarding the interrelation between workstations. This issue is a crucial concern because isolation within machinery is essential in food production processes to prevent contamination of materials, machines, and operators (Pakdel et al., 2023). By establishing a systematic layout framework, facility improvements can reduce unnecessary movements and excessive relocations and facilitate material handling (Besbes et al., 2020). This study aims to determine department configurations and identify potential risks associated with chocolate production.

METHOD

Initially, direct observation was undertaken at the FRC laboratory to identify issues on the shop floor and appraise the facility layout dedicated to chocolate machinery production. Subsequently, the focus shifted towards gathering essential data, encompassing machinery capacities, details on facilities and tools, a comprehensive overview of the existing layout, and collecting information on the workforce and the company's organizational structure. This planning procedure adheres to the systematic layout planning stages introduced by Muther and Hales (2010), as shown in Figure 1, where the nature of a product's production process shapes the layout type under consideration.

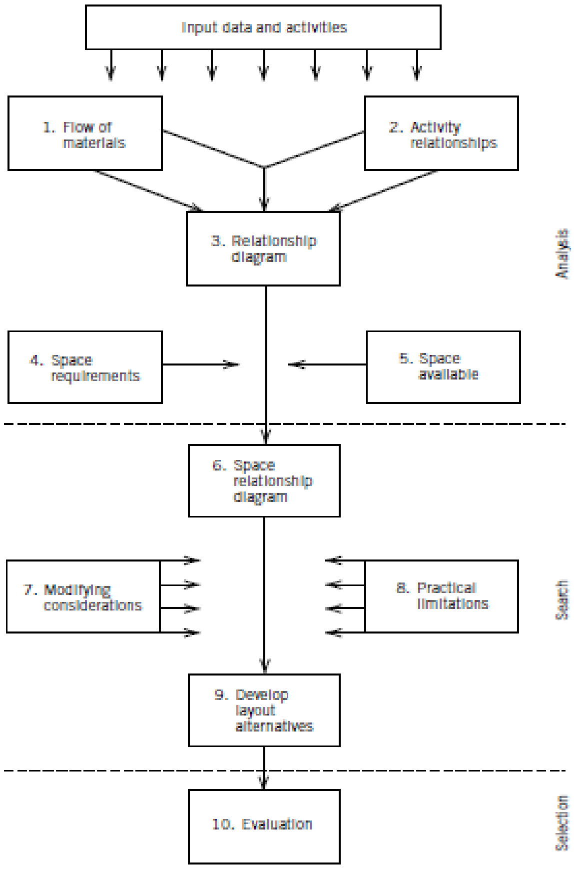

Figure 1.
Flowchart of systematic layout planning
Source: Muther and Hales (2010)

An essential aspect of the SLP flow, as shown in Figure 1, is that this study does not rely solely on numerical iterations to generate alternatives in steps 6 and 7. Instead, we incorporate adjustments, such as accounting for noise factors when no barriers are present to mitigate them. The noise validation in the existing floor during production is obtained using a sound meter with a 1x1 m coordinate point in the FRC every 10 seconds or 2 minutes. Therefore, there will be an average noise on 12 data obtained in each coordinate. Consequently, this leads to three layout comparisons: (1) the existing layout, (2) the ALDEP layout, and (3) a layout based on subjective judgment, modified according to step 8 in Figure 1.

Analysis of existing production process

Before designing improvements to the production facilities, the existing production process was identified through direct observation of the production facilities at the FRC laboratory. Data collection on machining dimensions and material flow was conducted to analyze the production layout from the existing production process. Furthermore, material flow was analyzed to acquire the flow process chart, which maps the entire process from start to finish. The flow process chart is a schematic drawing of the movement of materials, products, and workers (Heizer et al., 2020). In addition, the layout flow and production system category were also identified to determine the appropriate algorithm to solve the problem (Heragu, 2022).

Flow and department relationship analysis

Based on the existing machinery dimension data and flow process chart, further processing was carried out to determine the space requirement and REL charts. The REL chart constructed in this study is used as a supporting qualitative closeness rating to determine the ALDEP placement decision. The REL chart score in Table 1 is also discussed internally by conducting FGD with the FRC laboratory head, research team, and the FRC labor team.

The space requirement calculation in this paper uses a multiplier factor of 50% (Meyers & Stephens, 2013) to consider allowances and aisle rooms. Therefore, the space requirement data used in this paper has considered operator movements and material handling. The calculation of space requirements is carried out to determine the space needs of each department and the overall production facilities.

Table 1.
Closeness Rating Notation

Rating	Closeness
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary closeness
U	Unimportant
X	Undesirable

Source: Tompkins et al. (2010)

The REL chart was created to determine the degree of importance of two departments to be placed adjacent to each other. The process of assigning the importance level of the relationship is conducted pairwise. Each department pair has a specific notation that signifies the importance of their proximity. Five notations are used in the REL chart: A, E, I, O, U, and X, with explanations in Table 1. This paper justifies this closeness rating by considering the material flow, the worker's point of view, and material handling (Tompkins et al., 2010). The justification for the closeness rating used in this study is presented in Table 3.

After the Space Requirements of each department under review have been defined, the determination of Area Allocation is carried out as the first layout attempt to determine the space needs of each department. Before each department's area allocation is determined, each department's space requirements are converted into block units. Thus, the space needs of each department are represented by blocks. The blocks used in this paper are square with dimensions of 2 meters x 2 meters, so one block represents 4 square meters. This is intended to facilitate the allocation of each department into the production layout (Stephens & Meyers, 2013).

Proposed layout improvement design using ALDEP algorithm

This study utilizes the Automated Layout Design Program (ALDEP) algorithm to determine the layout within a production facility. Alternative quantitative methods, such as CORELAP and BLOCPLAN, were considered but not applied in this study due to the specific characteristics of the data. CORELAP's heuristic approach is comparable to ALDEP, suggesting limited additional benefit, while BLOCPLAN is more suited to layouts with uniform rows, which are not present in this case. The limited dataset further restricts the solution space, reducing the effectiveness of alternative methods. However, in future studies, these methods may prove valuable, particularly under a scale-up scenario where production complexity and equipment need to increase.

The layout design using the ALDEP algorithm is divided into two procedures: placement and selection. The selection procedure is conducted based on the highest degree of importance of the departments that still need to be placed. In contrast, the location selection procedure for these departments is carried out using a vertical sweep pattern (Figure 2). In general, the ALDEP algorithm used in this paper operates as follows:

(1) ALDEP will randomly select a department to be placed in the upper left corner of the layout. If there is no department with a degree of importance A, then ALDEP will look for a department with the next highest degree of importance, namely E, etc.
(2) ALDEP will then place the following department by selecting a department that has yet to be placed and has the highest degree of importance among other departments to the previously placed department. The selection process will be done randomly if there is more than one department with the same degree of importance.
(3) The process from step (2) is performed until all departments have been placed on the layout.
(4) The total score for the resulting alternative is calculated by summing up each score from the neighboring facility.

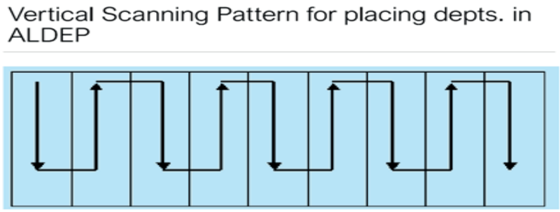

Figure 2.
Filling curve of ALDEP algorithm
Source: Heragu (2022)

After each department is placed, an evaluation of the layout produced by ALDEP is conducted. In this paper, the metric used to evaluate the performance of the design is the Total Closeness Rating (TCR). To put it simply, TCR is the summation of the degree of importance of proximity acquired from the REL chart of the adjoining facility (Tompkins et al., 2010). The higher the TCR value, the higher the proximity degree of importance of the adjacent facilities. The formulation of TCR is found in Equation 1.

$$TCR = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}x_{ij}$$

Where:

TCR	:	Total Closeness Rating
$x_{ij} \in \{0,1\}$	:	binary variable of adjacent department
f_{ij}	:	Proximity's degree of Importance
x_{ij}	:	1 if dept i and dept j are adjacent

To ensure the attainment of an optimal layout, the operationalization of ALDEP will be conducted over several iterations. The highest Total Closeness Rating (TCR) value will be selected from each iteration, ensuring that the layout to be implemented is the best.

Comparison of before and after proposed improvements

To examine the performance of the proposed layout with the current design, a comparison is made involving the Distance-based Flow metric. Material flow must be considered to determine the effort required or expended to move material from one machine to another in a company. Material flow is calculated from when the material is in the raw material area until it reaches the finished product area. The calculation of material flow is the summation of the multiplication of the amount of material carried by the distance between department centroids (Equation 2). Furthermore, determining the distance between two departments is done using a modified Euclidean distance approach, considering the positions of entry and exit access to prevent wall penetration during flow calculation (Heragu, 2022).

$$DBF = \sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}c_{ij}d_{ij}$$

Where:

DBF	:	Distance-based Flow
f_{ij}	:	Total material transferred from dept *i* to dept *j* per period
c_{ij}	:	Material handling cost from dept *i* to dept *j*
d_{ij}	:	Euclidean distance from dept *i* to dept *j*

The comparison between the proposed layout and the current layout is also conducted using the distance-based flow metric found in Equation 2 as a comparator between the two layouts. To gain further insight, discussions with facility management are conducted to obtain opinions from expert judgment originating from a food technology background regarding the applicability and feasibility of the proposed layout, as well as to make modifications to the proposed layout if deemed necessary. Consequently, this study strives to ensure that the resulting layout is feasible for application at the study site, specifically the FRC laboratory.

RESULTS AND DISCUSSION

Production process and space determination

There are six main processes for producing chocolate, as shown in Figure 3. Typically, two variants are created in the laboratory: dark chocolate and milk chocolate. These variants do not differ significantly in the process, which only involves the composition of cacao beans and milk powder. First, the cacao beans were roasted to reduce the contents of undesirable components, produce chocolate-specific aroma and flavor, and decontaminate the cocoa beans. Second, the roasted cacao was carried out from the chamber to rest and prepared to be ground in a winnower.

Furthermore, the ground cacao is mixed and heated in a conching machine to produce liquid chocolate. All chocolate particles should be coated with fat to achieve the desired viscosity. Lastly, the chocolate is moved to a tempering machine by adjusting the temperature so that the fat molecules crystallize evenly, resulting in a smooth, shiny finish when the chocolate sets and is ready to be packed. Based on the flow process chart, the chocolate production system is considered a flow shop production because each process only contains one successor or predecessor.

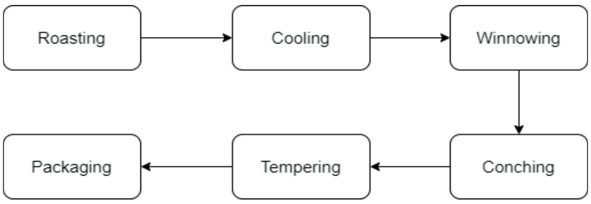

Figure 3.
Flow process chart of the chocolate production process
Source: internal analysis (2023)

The initial step in determining the layout involves identifying the spatial requirements for each production department and inventory by calculating the area occupied by machinery and space, with an additional 50% allowance, as shown in Table 2. This allowance is essential for optimizing material flow and accommodating the required space for machine operators and personnel in the inventory section. Moreover, the area needed will be used to allocate the number of blocks in area allocation.

REL Chart

The relationship between production and inventory departments is depicted using a REL Chart in Figure 4. Considerations for proximity relationships are made by examining material flow, and additional insights are gained from both the perspective of workers and material handling practices. Although specific justifications are given to assess the REL chart based on Table 3, the rationale is adjusted based on the production needs (Tompkins et al., 2010).

Table 2.
Space Determination

	Station	Length (m)	Width (m)	Area (m^2)
I. Production				
a. Roasting	1	1.16	1.56	1.82
b. Winnowing	1	0.95	1.38	1.33
c. Conching	1	1.17	1.55	1.83
d. Tempering	1	0.66	1.14	0.76
Subtotal				5.73
Allowance 50%				2.86
Total Production Space				8.59
II. Inventory				
a. Raw Material	1	0.42	3.60	1.51
b. Finished Goods	1	0.42	1.8	0.76
Subtotal				2.27
Allowance 50% (Material Handling)				1.13
Total Inventory				3.40

Source: internal analysis (2023)

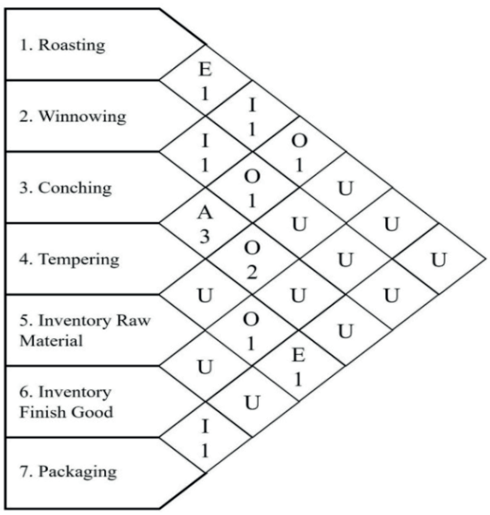

Figure 4.
REL chart for all departments
Source: Tompkins et al. (2010)

Table 3.
Closeness rating justification

Code	Justification	Notes
1	Ease of material flow	Directly moved to its successor
2	Material treatment	Special treatment on the material
3	Ease of monitoring	Accessible for controlling nearby departments

Source: Tompkins et al. (2010)

Area allocation

In allocating department placement grids, the grid unit divides the calculated area from the space requirements. Each grid unit has dimensions of 2 m x 2 m. Therefore, the grid requirements in Table 4 are determined by dividing the space requirements of each department by the area of one grid.

Table 4.
Blocks needed for department allocation

No	Department	Area (With allowance)	Blocks needed
1	Roasting	2.72	1
2	Winnowing	1.98	1
3	Conching	2.74	1
4	Tempering	1.14	1
5	Packaging	6.48	2
6	Inventory Raw Material	2.26	1
7	Inventory Finished Goods	1.13	1

Source: internal analysis (2023)

ALDEP algorithm

In designing a production layout using the ALDEP method, three inputs are required: (1) space requirements, (2) REL chart, and (3) area allocation. This data has been obtained through analysis in the previous subsection. Space requirements are used to identify the total area needed; the REL chart is used to lay the departments, such as which departments need to be placed adjacently and undesirably placed adjacent, whereas area allocation is used to determine the block requirements of each department considering the actual size of each department. It should be emphasized that the layout determination here uses block units, not their actual sizes. This is done to facilitate ALDEP configuring the layout and prevent a department from forming irregular or awkward shapes (Heragu, 2022).

The ALDEP algorithm is initiated by placing the first department and selecting the highest degree of importance near the REL chart. If there is more than one department with the highest degree of significance in proximity, one will be chosen randomly. In this study, due to the small number of departments on the observed site, the process of initiating the placement of the first department into the layout is alternated in each iteration. This study conducted four iterations with the departments placed first in the initiation process in the following order: (1) coaching, (2) winnowing, (3) tempering, and (4) roasting. After completing one iteration, the final TCR value is presented in Table 5.

Table 5.
TCR score for each iteration with different first departments being initiated

# of iteration	The first department initiated	Layouting Sequence	TCR
1	(3) Conching	(3) – (4) – (2) – (1) – (7) – (6) – (5)	89
2	(2) Winnowing	(2) – (1) – (4) – (3) – (5) – (6) – (7)	91
3	(4) Tempering	(4) – (3) – (2) – (1) – (7) – (6) – (5)	101
4	(1) Roasting	(1) – (2) – (4) – (3) – (5) – (7) – (6)	106

Source: internal analysis (2023)

Based on Table 5, the highest Total Cost Rating (TCR) value was obtained in the fourth iteration, with a TCR value of 106. In the initiation phase, the first department to be manually placed was the Roasting department (1). Subsequently, ALDEP heuristically selected the following department to be placed. The second department placed in the layout was the Winnowing department (2) because it has an Especially Important relationship with the Roasting department (1). Then, ALDEP found an Ordinary Closeness (O) relationship between the previously placed Winnowing department (2) and the Tempering department (4), so the third department was placed in the Tempering department. The fourth department placed in the layout was the Conching department (3) because it has an Important (A) relationship with the Tempering department (4). After the fourth department was placed, the following department selected was the Inventory of Raw Materials department (5) because it has an Ordinary Importance (O) relationship with the Conching department (3). The sixth department selected was the Packaging department due to its Especially Important (E) relationship with the Inventory of Raw Materials department, and the last department placed in the layout was the Finished Product Inventory department (6). The visualization of each department's placement is presented in the block diagram in Figure 5.

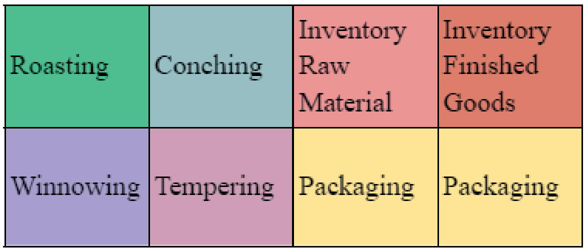

Figure 5.
Layout blocks generated by ALDEP on Iteration 4
Source: internal analysis (2023)

Proposed Layout Based on Expert Judgment

In addition to the layout design created using the heuristic method, namely ALDEP, this study also developed a qualitative design involving expert judgment and stakeholder preferences. Based on input from both parties, this study attempts to design a layout based on both inputs by translating the opinions of expert judgment and stakeholder preferences into a design language presented in Table 6. In addition, this study also strives to consider material flow as one aspect of layout design.

Table 6.
Translation from Stakeholder Input into Design Action

Stakeholder Input	Requirements	Design action
Conching machine is too loud and might endanger the workers health	Reducing Noise Hazard	Conching department will be placed in the middle of the facility with isolation treatment to reduce noise
Tempering process needs to be seen publicly by the visitors	Ease of observation	Tempering department will be placed near the window
Finished goods need to be available to be seen publicly and easy to be found by visitors	Ease of observation	Finished goods will be placed near the window

Source: internal analysis (2023)

This study prioritizes the design actions in Table 6 and places them into the layout priorly. After the mentioned departments, namely *conching*, *tempering*, and *finished goods storage*, have been put into the layout, the placement of departments other than these will be done with an attempt to consider material flow. The process of placing other departments is done by considering the proximity degree of importance based on the REL chart. More specifically, a department with the highest degree of importance with one of the three departments will be placed in the related department.

As an illustration, the packaging department has a significant (E) relationship with the tempering department and a significant (I) relationship with the finished goods department. Thus, the tempering department will be placed close to these two departments. In addition, optimizing flow is not the priority in the layout design produced in this subsection, so there will be a potential tradeoff that potentially lowers the distance-based measurement value of this layout. This layout will be evaluated along with the current and proposed layout generated by ALDEP.

Performance Evaluation of Proposed Layout

In evaluating the performance of the proposed layout, this study will compare three layouts: (1) the current layout, (2) a layout based on discussions with expert judgment originating from a food technology background, and (3) the proposed layout from the fourth iteration in the context of material flow. Material flow must be considered to determine the effort required or expended to move material from one machine to another in a company. The FRC UGM factory has several machines: roasting, winnowing, conching, and tempering. In addition, there are also areas for raw materials, packaging, and finished products. Material flow is calculated from when the material is in the raw material area until it reaches the finished product area. Material flow is calculated using a distance-based material flow approach with the formula found in Equation (2).

To perform the calculation, the material flow and the amount of material to be moved in the FRC UGM factory need to be identified first. The material flow in the FRC UGM factory occurs in the following order: (1) Inventory of Raw Materials, (2) Roasting, (3) Winnowing, (4) Conching, (5) Tempering, (6) Packaging, (7) Finished Goods Inventory. Additionally, the amount of material flowing from one department to another (in kg units) is presented in Table 7.

Unlike the constant material flow, which does not depend on the layout configuration, the distance between departments will rely on the observed layout. Thus, the distance between departments will differ between the current and proposed layouts. Therefore, the distance between departments must be identified in the proposed layouts. Illustrations of material flow concerning the current layout, the proposed layout based on expert judgment, and the proposed layout based on ALDEP are presented in Figures 6, 7, and 8, respectively.

Table 7.
Flow of materials

Process	From	To	Flow (kg)	Justification
1	Raw material	Roasting	10	Maximum capacity
2	Roasting	Winnowing	10	Maximum capacity
3	Winnowing	Conching	1.38	Maximum capacity
4	Conching	Tempering	13.3	Maximum capacity
5	Tempering	Packaging	10	Desired capacity
6	Packaging	Finished Goods Inventory	13	Include previous flow

Source: internal analysis (2023)

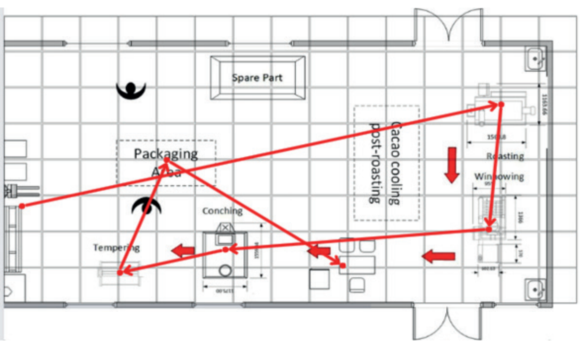

Figure 6.
Existing layout
Source: internal analysis (2023)

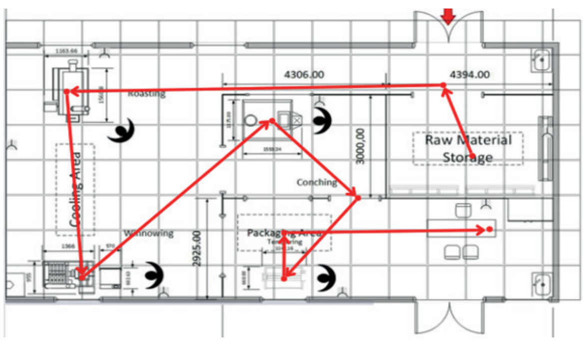

Figure 7.
Proposed Layout based on expert judgments
Source: internal analysis (2023)

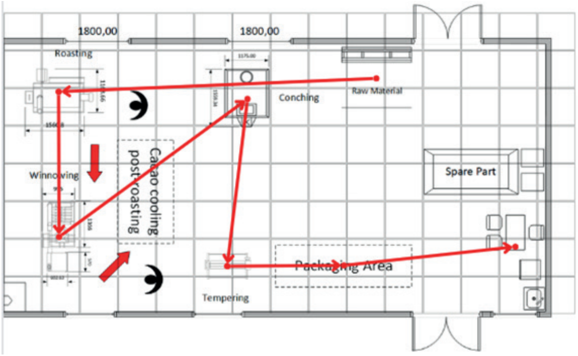

Figure 8.
Proposed Layout based on ALDEP
Source: internal analysis (2023)

A calculation is performed using the Euclidean approach to calculate the distance between departments. Generally, distance calculation is done by connecting a straight line to the two centroids of the two departments whose distance is to be calculated. This study uses a modification of the Euclidean Equation, considering the distance between the department centroid and the exit/entrance. This is done to obtain a more accurate distance. The results of the distance calculation between departments are presented in the form of a from-to-chart matrix for the current layout, the proposed layout based on discussion with expert judgment, and the proposed layout based on the ALDEP algorithm, which are presented in Table 8, Table 9, and Table 10, respectively.

Table 8.
From-to distance matrix of current layout

From / To	1	2	3	4	5	6	7
1	0	15.36	12.87	6.53	4.41	5.07	10.05
2		0	3.79	11.25	14.65	10.29	8.63
3			0	7.46	10.86	10.36	4.84
4				0	3.4	4.02	3.52
5					0	4.36	6.02
6						0	7.54
7							0

Source: internal analysis (2023)

Table 9.
From-to-distance matrix of Proposed layout based on discussion with expert judgment

From / To	1	2	3	4	5	6	7
1	0	12.42	13.65	6.22	8.42	7.1	2.54
2		0	5.73	6.2	11.02	9.7	14.96
3			0	9.43	5.29	6.55	12.01
4				0	4.82	3.5	8.76
5					0	1.32	6.78
6						0	5.46
7							0

Source: internal analysis (2023)

Table 10.
From-to-distance matrix of proposed layout based on ALDEP algorithm

From / To	1	2	3	4	5	6	7
1	0	8.68	12.53	3.92	8.89	5.81	8.12
2		0	3.87	5.14	9.05	12.09	16.1
3			0	8.61	5.18	8.22	12.23
4				0	4.97	6.95	10.96
5					0	3.08	8.07
6						0	4.99
7							0

Source: internal analysis (2023)

Once the distance between departments, material flow, and the amount of material flow have been identified, the layout evaluation using distance-based flow can be conducted. In simple terms, the calculation process for distance-based flow will sum up the total amount of material moved from department *i* to department *j*, multiplied by the distance from department *i* to department *j*. The notation *i* and *j* here represent the index of the departments, so the material flow from one department to another will be evaluated for each pair combination of two departments. The results of the calculation for each layout under analysis are presented in Table 11.

Based on the calculation results of the three observed layouts, it was found that the current layout has a distance-based value of 388.63 kg.m. Then, for the two proposed layouts designed in this study, the distance-based value is 397.74 kg.m for the proposed layout based on discussion results and 299.15 kg.m for the proposed layout using the ALDEP algorithm. A higher distance-based layout value indicates a higher material transfer cost because of the layout configuration. Therefore, the layout configuration with the lowest value should be chosen to evaluate the best-performing layout in the context of material transfer cost.

Table 11.
Summary of Distance-based flow calculations amongst three layouts

Scenario	Distance-based Value (Kg.m)
Existing	388,63
Proposed layout based on subjective judgment	397,74
Proposed layout based on ALDEP	299,15

Source: internal analysis (2023)

The distance-based value produced by the ALDEP algorithm performs better than the current layout, with an improvement of 23% from the current layout. On the other hand, the performance of the proposed layout based on discussion is worse than the current layout, where this layout performs 2% worse than the current layout. Therefore, from the perspective of material transfer cost, the layout produced by the ALDEP algorithm is recommended to be implemented to replace the current layout. This subjective judgment is crucial for future evaluations due to noise concerns validated through the noise heatmap in Figure 9. The permissible Threshold Limit Value (TLV) for noise in the workplace is 85 dBA for an 8-hour workday, and no individual should be exposed to noise levels exceeding 140 dBA, even momentarily (Keputusan et al., 1999). The heatmap indicates significant noise generated by the conching machine, highlighting an urgent need for implementing damping mechanisms and other noise reduction measures in alignment with SHE (Safety, Health, and Environment) standards.

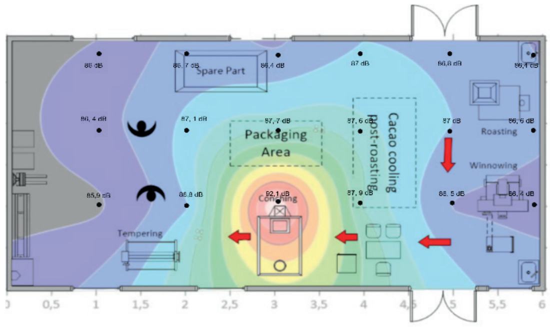

Figure 9.
Noise Heatmap on Existing Condition Source: internal analysis (2023)

CONCLUSION

The improvement in facility layout is undertaken to enhance the production scale, which initially operates on a laboratory scale, and to maximize its utilization towards a mass production scale. Thus, this enhancement provides a general overview of how to increase the productivity of FRC UGM. Based on the distance-based calculation values, the ALDEP scenario presents the most ideal solution with a 299.15 kg.m value. This indicates that ALDEP can optimize the distance-based aspects of the existing production floor conditions. Despite stakeholder discussions yielding a scenario with the highest distance-based value of 397.74 kg.m, the management has introduced constraints that do not seem to be considered in an “apple to apple” comparison, highlighting a limitation of this research. This issue arises due to the presence of specific noisy machines during operation.

Several related studies can be conducted to address the shortcomings in this paper. First, an analysis of noise reduction effectiveness concerning lab layout reconfiguration can be explored. Second, an experiment with alternative algorithms suitable for flow shop production processes is justified. Third, conducting a simulation study to analyze bottlenecks and line balancing would be valuable. This is essential because the four machines have varying capacities, and under ideal mass production conditions with minimal work-in-process (WIP), the number of machines should ideally adjust. Fourth, the scale of chocolate production should be adjusted to create an upscale scheme to incorporate more complex algorithms and modeling.

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BIBLIOGRAPHY

Al-Zubaidi, S.Q.D., Fantoni, G., and Failli, F. (2021). Analysis of drivers for solving facility layout problems: Literature review. *Journal of Industrial Information Integration*. https://doi.org/10.1016/j.jii.2020.100187

Amit, N., Suhadak, N., Johari, N., and Kassim, I. (2012). Using Simulation to Solve Facility Layout for Food Industry at XYZ Company. *IEEE*.

Ariesi, E.H., Pamungkas, A.P., and Ismoyowati, D. (2019). Penentuan Segmentation, Targeting, dan Positioning (STP) Minuman Bubuk Cokelat di Daerah Istimewa Yogyakarta. *Undergraduate Thesis*, Indonesia: Universitas Gadjah Mada.

Arifin, H. R., Farras, M.D., Robbani, M. F., Habiburrahman, M., and Batu, N. D. A. L. (2022). Optimizing Layout and Material Handling Cost: A Case Study of a Small and Medium-Sized Enterprise in the Food and Beverage Industry, in: *Proceedings of the 5th International Conference on Industrial & Mechanical Engineering and Operations Management*. pp. 854–865.

Atmasari, N. (2019). Produksi Kakao Tinggi, Kulonprogo Hanya Punya Satu Rumah Produksi. *Harian Jogja*. Accessed on 3 November 2023. Retrieved from https://jogjapolitan.harianjogja.com/read/2019/04/27/514/988313/produksi-kakao-tinggi-kulonprogo-hanya-punya-satu-rumah-produksi.

Barišić, V., Kopjar, M., Jozinović, A., Flanjak, I., Ačkar, Đ., Miličević, B., Šubarić, D., Jokić, S., and Babić, J. (2019). The chemistry behind chocolate production. *Molecules* 24. https://doi.org/10.3390/molecules24173163

Besbes, M., Zolghadri, M., Costa Affonso, R., Masmoudi, F., and Haddar, M. (2020). A methodology for solving facility layout problem considering barriers: genetic algorithm coupled with A* search. *Journal of Intelligent Manufacturing* (31), 615–640. https://doi.org/10.1007/s10845-019-01468-x

Dihni, V.N. (2022). 10 Negara Konsumen Cokelat Terbesar, Indonesia Masuk Daftar. *Katadata*. Accessed on 3 November 2023. Retrieved from URL https://databoks.katadata.co.id/datapublish/2022/07/20/10-negara-konsumen-cokelat-terbesar-indonesia-masuk-daftar.

Hari Prasad, N., Rajyalakshmi, G., and Sreenivasulu Reddy, A. (2014). A typical manufacturing plant layout design using CRAFT algorithm, in: *Procedia Engineering*. *Elsevier* Ltd, pp. 1808–1814. https://doi.org/10.1016/j.proeng.2014.12.334

Heizer, J., Render, B., Munson, C., and Charles L. (2020). Operations management: sustainability and supply chain management. *Pearson*.

Heragu, S.S. (2022). Facilities Design. *CRC Press*, Boca Raton.

Maghfiroh, M.F.N. (2021). Solving Multi-Objective Paired Single Row Facility Layout Problem Using Hybrid Variable Neighborhood Search. *Jurnal Teknik Industri* 23, 171–182. https://doi.org/10.9744/jti.23.2.171-182

Mebrat, B. and Haile, B. (2023). Job shop production layout optimization using combined CORELAP and

CRAFT algorithms. *AIP Conference Proceedings*. 2693. https://doi.org/10.1063/5.0118878

Meyers, F.E. and Stephens, M.P. (2013). Manufacturing Facilities Design and Material Handling, 5th ed. Prentice Hall, New Jersey.

Muther, R. and Hales. (2010). Systematic layout planning, 4th ed. Management and Industrial Research Publications, Georgia.

Ojaghi, Y., Khademi, A., Yusof, N.M., Renani, N.G. and Hassan, S.A.H.B.S. (2015). Production layout optimization for small and medium scale food industry, in: *Procedia CIRP*. Elsevier B.V., pp. 247–251. https://doi.org/10.1016/j.procir.2014.07.050

Pakdel, M., Olsen, A., and Bar, E.M.S. (2023). A Review of Food Contaminants and Their Pathways Within Food Processing Facilities Using Open Food Processing Equipment. *Journal of Food Protection*. https://doi.org/10.1016/j.jfp.2023.100184

Palomo-Romero, J.M., Salas-Morera, L., and García-Hernández, L. (2017). An island model genetic algorithm for unequal area facility layout problems. *Expert Systems with Applications*. 68, 151–162. https://doi.org/10.1016/j.eswa.2016.10.004

Puspita, I.A., Iqbal, M., Pratami, D., and Pratomo, A. (2017). Production facility layout design using blocplan algorithm. *Advanced Science Letters*. 23, 3917–3920. https://doi.org/10.1166/asl.2017.8260

Rifai, A.P., Alfithra, A.R., Al'adiat, C.F., and Sari, W.P. (2023). Facility Layout Planning for Pyrolyzer Production Using Automated Layouts Design Program (ALDEP) Method. *OPSI* 16, 165. https://doi.org/10.31315/opsi.v16i1.8745

Saifurrahman, A., and Sudiarso, A. (2022). Applying Multi-objective Metaheuristics to Unequal Area Facility Layout Problem by Using Sub-array Matrix Slicing Approach. *Thesis*, Indonesia: Universitas Gadjah Mada.

Stephens, M.P., and Meyers, F.E. (2013). Manufacturing Facilities Design and Material Handling, 5th ed. Prentice Hall, New Jersey. https://doi.org/10.2307/j.ctv15wxptd

Suhardini, D., and Rahmawati, S.D. (2019). Design and improvement layout of a production floor using automated layout design program (ALDEP) and CRAFT algorithm at CV. Aji Jaya Mandiri, in: *IOP Conference Series: Materials Science and Engineering. Institute of Physics Publishing*. https://doi.org/10.1088/1757-899X/528/1/012062

Tambunan, M., Ginting, E., and Sari, R.M. (2018). Production facility layout by comparing moment displacement using BLOCPLAN and ALDEP Algorithms, in: *IOP Conference Series: Materials Science and Engineering. Institute of Physics Publishing*. https://doi.org/10.1088/1757-899X/309/1/012032

Tompkins, J.A., White, J.A., Bozer, Y.A., and Tanchoco, J.M.A. (2010). Facilities planning, 4th ed. *Wiley*.