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Increasing Production Productivity by Improving Facility Layout Using the BLOCPLAN Method, Systematic Layout Planning, and Differential Evolution Algorithm

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ABSTRACT
A furniture company that produces dining chairs, coffee tables, and sofa has a common problem, namely the company's inability to complete production targets within the specified time period. These general problems are the result of less efficient production paths because there is backtracking, by-passing, cross movement, and material transfer between stations that are far apart. This problem can be resolved by using improvements to the production floor layout using BLOCPLAN, Systematic Layout Planning, and Algorithms Differential Evolution. This research aims to design a production floor layout that can minimize distance, total movement moment, and material handling costs, with a line efficiency rate above 75%. The results of this research show that the proposed layout was selected using the Differential Evolution Algorithm with a displacement distance of 231.24 meters, a total displacement moment of 15,820.93 meters/month, material handling costs of IDR 1,865,920/month, and a line efficiency rate of 81.94 %.
Keyword: Bactracking, By-Passing, Cross Movement, BLOCPLAN, Systematic Layout Planning, Differential Evolution

ABSTRAK
Perusahaa furnitur yang memproduksi kursi makan, meja tamu, dan sofa memiliki permasalahan umum, yaitu ketidakmampuan perusahaan dalam menyelesaikan target produksi dengan jangka waktu yang telah ditentukan. Permasalahan umum tersebut merupakan akibat dari lintasan produksi yang kurang efisien karena terdapat *backtracking, by-passing, cross movement*, dan perpindahan material antar stasiun yang berjauhan. Permasalahan ini dapat diselesaikan melalui perbaikan tata letak lantai produksi dengan menggunakan BLOCPLAN, *Systematic Layout Planning*, dan Algoritma *Differential Evolution.* Penelitian ini bertujuan untuk merancang ulang tata letak lantai produksi yang dapat meminimalkan jarak, total momen perpindahan, dan ongkos *material handling*, dengan *line efficiency rate* diatas 75%. Hasil penelitian ini menunjukkan *layout* usulan terpilih menggunakan Algoritma *Differential Evolution* dengan jarak perpindahan sebesar 231,24 meter, total momen perpindahan sebesar 15.820,93 meter/bulan, ongkos *material handling* sebesar Rp 1.865.920 /bulan, dan *line efficiency rate* sebesar 81,94%.
Keyword: *Bactracking, By-Passing, Cross Movement, BLOCPLAN, Systematic Layout Planning, Differential Evolution.*

1. Introduction

The development of science and technology has a significant impact on all industrial activities. One tangible effect is in the layout organization of facilities, especially in anticipating various changes that may occur. This involves better future planning, the development of new equipment, and integration with related tasks. An

optimal facility layout, tailored to the needs of the company, can be key to improving production time efficiency and facility planning costs, which significantly affect the company's operational processes [1]

Facility layout planning relates to the design, layout, location, and placement of people, machines, and activities within a manufacturing/service system that involve the physical environment or place [2]. The plant layout or facilities layout is the process of arranging factory facilities to ensure smooth production. In the plant layout, there are two main elements that are organized: the arrangement of machines (machine layout) and the arrangement of the departments within the factory (department layout) [3][4]. In designing the layout of manufacturing facilities or plant layout, the physical elements that need attention are machines, equipment, operators, and materials. This is achieved by arranging machines and equipment in such a way that they are not too far apart without violating ergonomic principles [5][6].

CV CJ is a company that produces various types of furniture, including chairs, cabinets, tables, sofas, kitchen sets, wallpaper, and beds. These products will be marketed to several furniture stores. This company has 13 stations consisting of raw material storage station, measuring station, cutting station 1, cutting station 2, drilling station 1, drilling station 2, engraving station, assembly station, planning station, polishing station, painting and polishing station, foam and fabric installation station, and product storage. This company uses Make to Order (MTO). The type of layout used is a process layout.

However, the actual layout still results in long and inefficient material movement paths. Therefore, improvements are needed using the BLOCPLAN method, Systematic Layout Planning (SLP), and Differential Evolution Algorithm. This approach aims to optimally rearrange the sequence of production stations based on activity relationships, and computational optimization results to minimize material movement distance and increase production efficiency. The advantages of this solution are increased production volume and operational cost efficiency, which can be seen from the increase in Line Efficiency Rate (LER) and a decrease in total material handling costs. However, the disadvantage is the need for additional costs to rearrange production facilities that require careful planning and initial investment. [9][10].

One of the common problems found in this business is the company's inability to meet the production targets set within a certain timeframe. This indicates a lack of efficiency in the production process, which impacts the delay in order completion. Based on the data obtained regarding production targets and actual production achievements, it is evident that the company has yet to meet the planned targets. This discrepancy is particularly clear in the year 2023, especially for product types such as dining chairs, coffee tables, and sofas, as shown in Table 1.

Table 1. Production Targets and Achievements in 2023

Product	Target (Units)	Ontime Order Fulfillment (Units)	Percentage of Achievement (%)
Coffee Tables	115	85	74
Dining Chairs	162	132	81
Sofa	74	5058	78
Average			77.66

Based on Table 1, the percentage of achievement of the average production target of this company for coffetables, dining chairs, and sofa in 2023 is 77.66%. The average percentage of achievements obtained does not meet the company's standard production target, namely 100%. One of the reasons why the 100% production target was not realized was the inefficiency of the production line due to the irregular placement of work stations, which resulted in a long and inefficient production process flow.

Other problems found on this company is trajectory less production efficient consequence exists by pass, cross movement, flow back (backtracking), and the company is also lacking consider distance between every station Work so that increase cost material handling will be used at the time move material from One station to station furthermore. This problem can affects the total movement distance and material handling costs that will be the more big. Actual layout that explains the flow of materials in the production process dining chair, coffee table, and sofa can be seen in Figure 1.

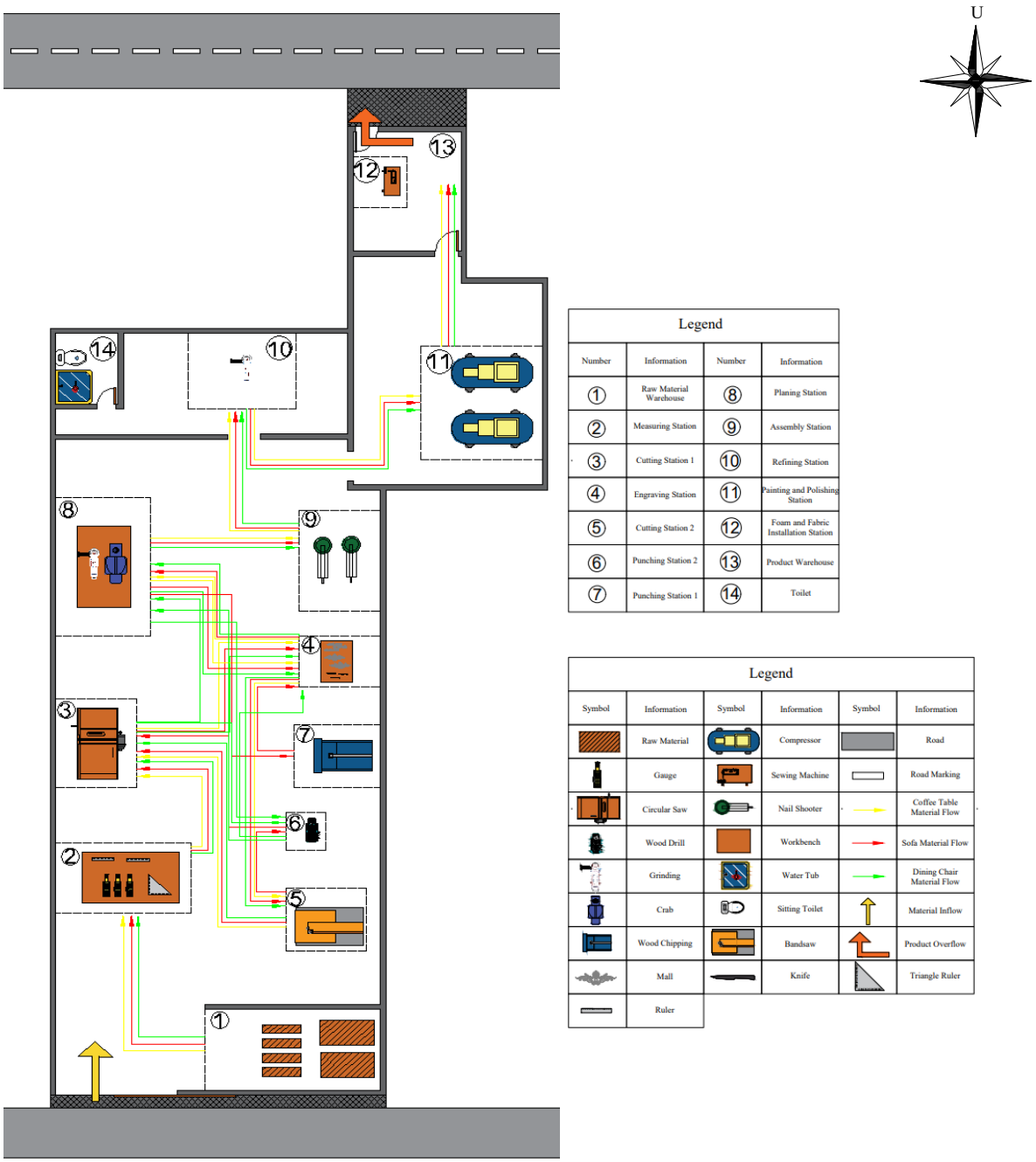

Figure 1. Actual Layout

Based on Figure 1, there are four main problems related to material flow inefficiencies. The first problem is backtracking in material movement, occurring from the engraving station to cutting station 2, the planning station to punching station 1, cutting station 1 to punching station 2, the planning station to punching station 2, and the planning station to the engraving station, resulting in a total distance of material movement of 135.65 meters, which leads to inefficient flow. The second problem is by-passing, where material moves directly from punching station 2 to the grinding station, skipping the previously required steps at punching station 1 and the engraving station, thereby increasing material handling costs and production lead time. The third issue involves cross movement (intersection of material flows), such as from cutting station 1 to the engraving station intersecting with punching station 2 to the cutting station, and from cutting station 1 to the engraving station intersecting with the drilling station to punching station 1, which can cause congestion and flow disruptions. Lastly, there is a considerable distance of 18 meters between the drilling station and punching station 2, resulting in inefficient material transfer between two consecutive stations and potentially disrupting the production process.

Line Efficiency Rate (LER) is a value that shows the efficiency of material flow on the production floor with a good flow efficiency threshold value of ≥75% of the shortest distance of the flow [7]. Line efficiency rate is calculated by comparing the closest distance (rectilinear distance) with the actual distance (aisle distance) on the layout [8]. Based on the actual layout, total distance includes an aisle distance of 14,979.37 meters per month and a rectilinear distance of 11,104.52 meters per month. So, from results calculation obtained mark Line Efficiency Rate (LER) layout actual amounting to 65.10%.

Methods used to improve the layout uses the BLOCPLAN method, Systematic Layout Planning, and Differential Evolution algorithm. BLOCPLAN is a program being developed for do layout design functioning facilities for minimize distance between facility or maximizing connection proximity between facility. This method requires data on station names, station areas, and activity relationship charts (ARC) [9]

Systematic Layout Planning method is a method that aims to design a layout by considering the degree of relationship between departments. Required data on this method are ARC, worksheet and ARD [12][13][14]. Layout Design using Systematic Layout Planning (SLP) created to solve problems involving various activity such as production, transportation, warehousing, supporting services, assembly and other office activities [15][16]

Differential evolution algorithm is a program for determining the proposed layout of the production floor. The data required to use this algorithm is the area of each work station, material flow data, movement frequency data and material handling costs/meters [17]. The main function of this method is the total material of distance moved or it can also be the total cost of moving the material. This method aims to minimize the costs of moving materials on the production floor and between departments [18].

Election alternative selected layout done with determine distance, total moment displacement, costs material handling smallest, with line efficiency rate biggest. In fact, implementation alternative selected need mentioned costs cost arrangement. Cost arrangement is necessary costs issued for organize return every facility become something arrangement desired facilities, in matter This is arrangement facility based on alternative selected. Cost arrangement covers costs used for move machine, crushing wall, add track material handling, operator costs, and so on. Arrangement costs are needed to estimate the costs that will be incurred to implement the selected alternative layout[18].

2. Research Methodology

The research carried out is included in the type of descriptive research. Descriptive research aims to describe systematically, factually and accurately the facts and characteristics of a particular object or population [19]. In the research process, information was collected through techniques such as observation of the layout, analysis of distances and sizes at each station and interview techniques with workers.

The method used to analyze the data in this research is to calculate the distance using the aisle distance method and calculate the Line Efficiency Rate (LER) on the actual and proposed production floor layouts, then use the BLOCPLAN, Systematic Layout Planning, and Differential Evolution methods to obtain the proposed layout and compare the actual layout with the proposed layout by paying attention to the movement distance, total movement moment, and the smallest material handling costs and the largest line efficiency rate to determine the best layout [18][20][21].

3. Results and Discussion

3.1. Research methodology and data collection

The stages carried out in this research are measuring the cycle time of each work element from each department, measuring the dimensions of each department, collecting work station condition data, measuring movement distances between departments, calculating the number of movement frequencies, making efficient trajectories, making optimal layouts using the Differential Evolution algorithm, calculating the actual total movement moments and after repairs.

3.2. Calculation of Distance Between Stations, Total Moving Moment, Material Handling Costs, and Line Efficiency Rate (LER) in the Actual Layout

Calculation of aisle distance and rectilinear is needed to calculate the longest and shortest distance that will be traveled during the production process. Here is the formula [20].

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

Where:
x_i = x-coordinate at the center of facility i
y_i = y-coordinate at the center of facility i
d_{ij} = distance between the center of facility i and j

From the results of the aisle distance and rectilinear distance calculations, the total displacement moment was 21,197.23 Results meters/month for the aisle distance method and 14,857.78 meters/month for the rectilinear distance method .The material handling costs are calculated based on aisle distance. Actual layout calculations, material handling costs are obtained at IDR 2,500,000/month. The Line Efficiency Rate (LER) will be calculated using the following formula [20].

$$LER = \left(1 - \frac{\text{aisle distance} - \text{rectilinear distance}}{\text{rectilinear actual distance}}\right) \times 100\% \quad (2)$$

$$LER = 65.10\%$$

The calculation results Line Efficiency Rate (LER) is obtained efficiency layouts actual amounting to 65.10%. Minimum efficiency threshold said good if own mark efficiency above 75 % [7]. Based on results the actual layout LER value still is at below the threshold limit mark good efficiency. The calculation results line efficiency rate obtained show that still not enough efficient so that needed layout improvements production.

3.3. Calculation of Number of Machine Requirements

The calculation of number of machine requirements is carried out to determine the number of machine requirements for each station that uses the machine. The number of machine requirements is influenced by the operating time of each machine, the number of products produced, operating working hours and efficiency factors. An example of calculating the number of circular saw machines used for a production process with operating working hours of 25 days (8 working hours/day) is as follows [5].

$$N = \frac{T}{60} \times \frac{P}{DxE} \quad (3)$$

$$N = 1$$

Where:
N = Number of machines/operators required for production operations
T = Total processing time required for the production process (minutes/unit/product)
P = The number of products that each machine must make per period time (units/year)
D = Machine operating hours
E = Machine work efficiency factors caused by set up, breakdown and idle time (0,9)

Recapitulation of the calculation of the number of machines needed at each work station can be seen in Table 2.

Table 2. Number of Machine Requirements

Machine	Amount Machine Theoretical	Amount Machines Required (Units)	Amount Machine Actual (Units)
Circular saw	0.82	1	1
Bandsaw	1.85	2	1
Wood Drill	0.44	1	1
Wood Chipping	0.11	1	1
Crab	1.45	2	1
Grinding 1	0.63	1	1
Grinding 2	0.38	1	1
Paint Compressor	0.83	1	2
Sewing Machine	0.51	1	1

3.4. Determination Alternative Layouts Selected with Using the BLOCPLAN Method, Systematic Layout Planning, and Differential Evolution Algorithm

Based on several alternative layouts that have been designed, the best layout will be selected based on the total distance, total moment of movement and the smallest total material handling costs with the largest layout efficiency value. A comparison of the proposed layout of each method can be seen in Table 3.

Table 3. Comparison of Actual Layout, BLOCPLAN, Systematic Layout Planning, Differential Evolution Algorithm

Layouts	Total Distance (m)	Total Displacement Moment (m/ month)	Total Cost Material Handling (Rp/ month)	Line Efficiency Rate (%)
Actual	314.2	14,979.37	2,500,000	65.10
BLOCPLAN	263.58	17,776.44	2,096,553	76.80
Systematic Layout Planning	282	12,738	2,125,923	75.02
Differential Evolution Algorithm	231.24	15,820.93	1,865,920	81.94

Based on the comparison of usual layouts, the selected proposed layout is the layout resulting from the differential evolution algorithm with a total distance of 231.24 meters, total displacement moment of 15,820.93 meters/month, total material handling costs per month amounting to IDR 1,865,920, and a line efficiency rate of 81.94%. Final 2D layout, which was designed based on the production floor layout in the selected proposed layout, can be seen in Figure 2.

The income obtained in April for the actual layout came from sales of dining chairs, coffee tables and sofa, namely IDR 46,350,000 . Expenditures made in April for the actual layout came from monthly employee salaries, electricity costs and raw material costs, namely IDR 29,825,000. Based on the income and expenses obtained in April, profits are obtained by subtracting the amount of income from the amount of expenses. Therefore, the company makes a profit of IDR 16,525,000.

After being given a proposed production floor layout, a comparison of profits is made with the actual production floor layout. To calculate profits for the proposed production floor layout, the number of products produced is calculated by comparing the distance traveled by the product on the actual production floor layout with the distance of the proposed layout for a month. Products produced on layout actual can seen in Table 4.

Table 4. Products Generated in Layout Actual

No	Types of products	Amount	Percentage
1	Coffee tables	9	32%
2	Dining chairs	13	46%
3	Sofa	6	21%
Total		**28**	**100%**

Calculation amount products produced on the layout proposal use comparison mark upside down, yes use formula as following [22]

$$\frac{X_1}{X_2} = \frac{Y_2}{Y_1} \tag{4}$$

Where X_1 is Amount products produced on the layout actual, X_2 is Amount products produced on the layout proposal, Y_1 is Total distance moment changes to the layout proposal, and Y_2 is Total moment distance changes to the layout actual. Calculation amount product on the proposed layout can seen as following.

$X2 = 29.57 \approx 29$ units/ month

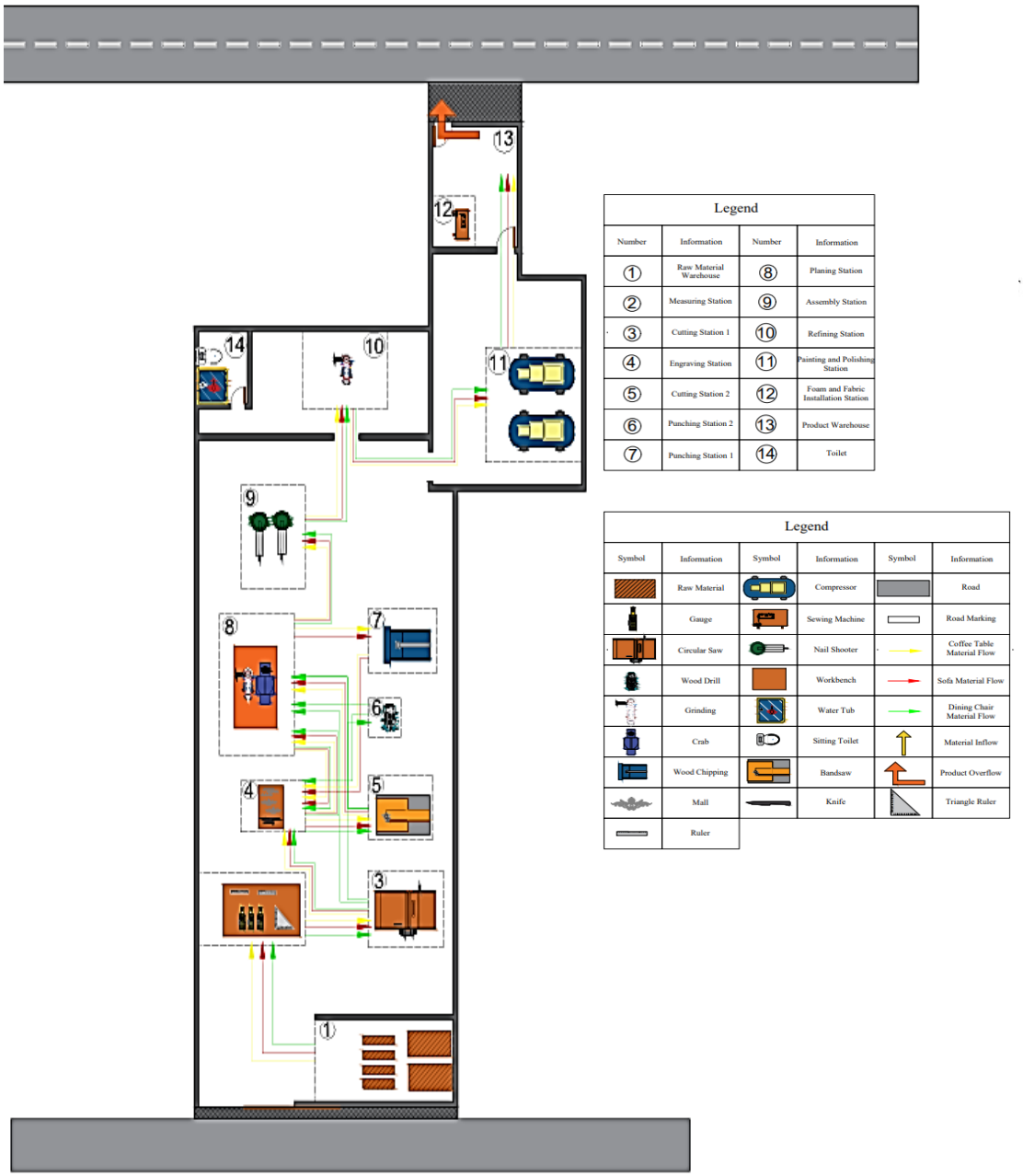

Figure 2. Final 2D Layout

Based on calculation use comparison mark upside down, then obtained addition number of units available generated in the layout proposal amounting to 8 units, so the total product produced during a month amounting to 29 units. So, it's done calculation amount product for every type product with use percentage every type product on actual layout. Amount every type product proposed layout can see in Table 5.

Table 5. Amount Products in Layout Proposal

Amount Product	Types of products	Amount
29	Coffee table	10
	Dining chairs	13
	Sofa	6
Total		29

3.5. Analysis of Production Target Achievement

After designing the facility layout, the company experienced an increase in production so that it was able to increase the achievement of the company's production targets. The calculation of achieving the production

target for the proposed layout is based on the percentage of achievement in the actual layout with the aim of finding out the number of products in the proposed layout that have exceeded the production target in the actual layout which can be seen in Table 6.

Table 6. Comparison of Achievement of Production Targets in 2024

Product	Production Target/Year (Units)	Production Achievement/Year (Units)		Percentage of Achievement (%)		Increased Achievement (%)
		Actual	Proposed	Actual	Proposed	
Dining Chairs	124	156	156	125,81	125,81	0,00
Coffee Table	110	108	108	98,18	109,09	10,91
Sofa	62	72	84	116,13	116,13	0,00

Based on Table 6, by implementing the proposed layout, the company is able to complete the production target within the specified time period.

4. Conclussion

Based on the processing and analysis results, the conclusions of this research are are the actual layout results in a total distance of 314.2 meters, a total displacement moment of 14,979.37 meters per month, and material handling costs of IDR 2,500,000 per month, with a Line Efficiency Rate (LER) of 65.10%. In comparison, the layout proposal using the differential evolution algorithm achieved a total displacement distance of 231.24 meters, a total displacement moment of 15,820.93 meters per month, material handling costs of IDR 1,865,920 per month, and a Line Efficiency Rate (LER) of 81.94%, indicating that the proposed layout is more efficient, exceeding the efficiency threshold of 75%. The cost for improving the layout of CV CJ's production floor is IDR 960,000. With the actual layout, the company produces 28 units of product with a profit of IDR 16,525,000 per month, while the proposed layout increases production to 29 units, resulting in an additional unit per month.

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