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Facility Layout Redesign Using BLOCPLAN Algorithm to Minimize Material Handling Distance and Cost in Black Tea Production Facility

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Abstract

Purpose – This study aims to redesign the production facility layout at PTPN 1 Regional 5 Wonosari Tea Plantation, Malang, using the BLOCPLAN algorithm, with the primary objective of minimizing material transfer distance and Material Handling Cost (MHC) across nine inter-departmental material flows in a black tea Crushing, Tearing, and Curling (CTC) production facility.

Methodology – Data collection employed three methods: direct observation (facility dimensions and inter-departmental distances); document review for material flow frequency data to construct the From-To Chart (FTC); and structured interviews with field supervisors to establish the Activity Relationship Chart (ARC). The existing layout was evaluated using the Rectilinear Distance formula to calculate total MHC. The BLOCPLAN algorithm was executed with dual FTC and ARC inputs, generating 20 layout iterations from which the five layouts with the highest Adjusted R-Score were selected. The best proposed layout (LU5) was identified and evaluated through rectilinear distance calculation and MHC computation for all nine material flows, then compared directly against the existing layout, supplemented by scaled grid and final floor plan visualizations.

Findings – The proposed BLOCPLAN LU5 layout achieved a total material transfer distance of 105.5 meters—a 70.75% reduction from the existing 360.7 meters—and a total daily MHC of IDR 33,251,558.71, a 28.89% reduction from the existing IDR 46,782,284 (daily savings of IDR 13,530,725.29). The most critical flow, D1–D2 (Fresh Leaf Receiving to Withering), was reduced from 150 meters to 16 meters (89.33%), cutting its daily MHC from IDR 9,866,374 to IDR 1,052,412.48. The BLOCPLAN layout successfully eliminated backtracking and aligned departments with the sequential CTC production process.

Originality – This study provides an original contribution by applying the BLOCPLAN hybrid algorithm to a black tea CTC processing facility. The research presents a comprehensive comparison of distance and MHC changes, supplemented by a scaled departmental grid visualization and the final recommended floor plan, offering a granular and visually grounded analysis that demonstrates which specific inter-departmental flows drive the greatest efficiency gains.

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Introduction

PT Perkebunan Nusantara 1 (PTPN 1) Regional 5 Wonosari Tea Plantation, located in Singosari, Malang, East Java, is one of Indonesia's primary black tea manufacturers employing the Crushing, Tearing, and Curling (CTC) processing method. The plantation produces an average of 3,085.92 kilograms of finished black tea per operational day, with approximately 90% of its output destined for international export markets including the United States, the Netherlands, Pakistan, and Australia (Annafi'ah, 2023). Despite its significant export contribution, the production facility confronts persistent inefficiency rooted in its physical layout configuration.

The existing production facility encompasses 10 operational departments—from Fresh Leaf Receiving (D1) to Temporary Storage (D10)—arranged in a configuration that evolved reactively over decades of incremental machine additions rather than through systematic planning. This organic growth has produced a layout characterized by cross-routing and material backtracking, where the most critical flow from Department 1 (Fresh Leaf Receiving) to Department 2 (Withering) spans 150 meters. This distance requires the monorail transport system to operate 42 trips per day, with each trip consuming 300 seconds (150 m ÷ 0.5 m/s), generating a daily MHC contribution of IDR 9,866,374 from this single flow alone. Across all nine material flows, the existing layout generates a total daily MHC of IDR 46,782,284 with a cumulative material transfer distance of 360.7 meters (Cikal, 2026).

The urgency of addressing layout inefficiency in tea processing is amplified by the perishable nature of the raw material. Fresh tea leaves must be processed within 4 to 6 hours of harvest to prevent uncontrolled enzymatic oxidation that irreversibly degrades product quality (Harsanti, Purwayantie, & Fadly, 2024). Every minute of unnecessary transport time therefore carries a dual penalty: direct cost in the form of MHC, and indirect cost through quality degradation risk. The existing 300-second monorail journey from D1 to D2 per trip—multiplied by 42 daily trips—means 210 minutes per day are consumed solely by this single transport link.

The black tea industry in Indonesia occupies a strategically important position in the national agricultural export economy. The CTC processing method employed at Wonosari Tea Plantation is particularly prevalent in bulk tea production for export markets, as it produces a consistent, fine-particle tea product well-suited to tea bag manufacturing. However, the capital-intensive nature of CTC processing equipment—including the Rotorvane, CTC machine, Vibrating Fluid Bed Dryer (VFBD), and automated sorting machines—creates strong physical layout constraints, as these machines are large and must be arranged in strict processing sequence to maintain product quality through the withering-grinding-fermentation-drying chain. This combination of perishability pressure, equipment rigidity, and high production volume makes facility layout optimization particularly consequential in this context.

Layout inefficiency in tea processing facilities has been documented as a persistent industry challenge. Hadiputri et al. (2022) observed that many plantation-based processing facilities share a common development pattern: the initial layout was designed for a fraction of current capacity, with additional machines and departments added reactively as volumes grew. At PTPN 1 Regional 5 Wonosari, this pattern manifests in the D1–D2 flow distance of 150 meters and the D9–D10 backtracking, both structural relics of the facility's expansion history rather than deliberate design choices.

This study applies the BLOCPLAN algorithm to redesign the production facility layout at PTPN 1 Regional 5 Wonosari Tea Plantation with the specific objective of minimizing material transfer distance and MHC. The study focuses on generating and evaluating alternative layouts through BLOCPLAN's Adjusted R-Score mechanism, selecting the optimal configuration (LU5), visualizing the proposed layout through both a scaled departmental grid and the final recommended floor plan, and providing a comprehensive per-flow comparison of distance and MHC outcomes between the existing and proposed layouts. The scope is specifically bounded to the BLOCPLAN method as a standalone redesign tool to provide a detailed examination of its application process, iteration selection rationale, and per-flow

outcome analysis in the context of a black tea CTC processing environment—a sector not previously documented in the BLOCPLAN application literature.

Literature Review

Facility Layout Planning and Material Handling Cost

Facility layout planning refers to the systematic arrangement of physical facilities—including machinery, workstations, departments, and supporting infrastructure—within a production environment to optimize material flow, minimize transportation distance, and reduce operational costs (Hartari & Herwanto, 2021). An effective facility layout directly reduces waste of motion, minimizes material handling time, and improves production throughput by ensuring that departments with high interaction frequency are placed in close proximity. Poor layout design, conversely, creates backtracking flows, cross-routing conflicts, and capacity bottlenecks that compound over time as production volumes increase.

The primary metric for evaluating layout efficiency in manufacturing environments is the Material Handling Cost (MHC), known in Indonesian literature as Ongkos Material Handling (OMH). MHC quantifies the total cost of moving materials between departments, calculated as the product of inter-departmental distance, material flow frequency, and the cost per unit distance for the respective handling equipment (Salsabila et al., 2023). Inter-departmental distance is measured using the Rectilinear Distance formula:

$$d(i,j) = |Xi - Xj| + |Yi - Yj| \quad \text{..... (1)}$$

where Xi and Yi are the centroid coordinates of the origin department i, and Xj and Yj are the centroid coordinates of the destination department j. This metric is preferred over Euclidean distance in facility layout problems because it accurately reflects the right-angle travel paths of material handling equipment within rectangular floor layouts (Tarigan & Zetli, 2022). Total daily MHC is calculated as:

$$MHC = \Sigma\, [d(i,j) \times f(i,j) \times c(i,j)] \quad \text{..... (2)}$$

where f(i,j) is the daily transfer frequency between departments i and j, and c(i,j) is the unit cost per meter for the handling equipment (IDR/meter).

The total daily MHC serves as the primary performance metric for comparing alternative layout configurations. Prior studies in agroindustrial contexts have established that MHC reductions of 20–35% are achievable through systematic layout redesign (Putri & Suhartini, 2024; Sihombing et al., 2024), while more dramatic improvements exceeding 60–70% are possible when the existing layout contains critical long-distance flows (Tarigan & Zetli, 2022). The magnitude of MHC savings is heavily dependent on the unit handling cost per meter c(i,j), which varies substantially across different equipment types. Equipment with high unit costs amplifies the financial impact of even small distance changes, making identification and prioritization of high-cost flows a critical component of layout analysis.

BLOCPLAN Algorithm

BLOCPLAN (Block Layout Overview with Computerized Planning) is a hybrid facility layout algorithm that integrates the strengths of both construction and improvement algorithms into a unified computational framework (Muharni, 2022). Unlike purely construction-based algorithms such as ALDEP—which generate layouts from scratch based solely on qualitative departmental relationships—or purely improvement-based algorithms such as CRAFT—which optimize existing layouts based solely on quantitative material flow costs—BLOCPLAN simultaneously processes both types of input data, namely the From-To Chart (FTC) for quantitative flow data and the Activity Relationship Chart (ARC) for qualitative proximity priorities (Ghozi & Hermanuadi, 2023). This dual-input architecture makes BLOCPLAN particularly effective in production environments where departments must satisfy both cost efficiency and operational compatibility constraints.

The algorithm operates by dividing the total floor area into horizontal bands (pita) and positioning departments within these bands based on proximity scores derived from the ARC. The quality of each generated layout is evaluated using the Adjusted R-Score, a parameter ranging from 0 to 1 where values approaching 1 indicate superior layouts with higher departmental adjacency satisfaction and lower material flow moment (Daya, Sitania, & Profita, 2019). A key theoretical advantage of BLOCPLAN over CRAFT is its treatment of X-type ARC relationships (Undesirable proximity): while CRAFT—operating purely on cost minimization—may inadvertently place mutually incompatible departments adjacent to each other if doing so reduces total MHC, BLOCPLAN inherently penalizes configurations that violate X constraints, ensuring that the generated layouts respect operational incompatibilities such as humidity separation requirements in food processing environments (Tarigan & Zetli, 2022).

BLOCPLAN generates multiple layout iterations and ranks them by Adjusted R-Score, providing the designer with a curated set of near-optimal alternatives for MHC-based final selection. Previous research has demonstrated BLOCPLAN's effectiveness across various industrial contexts. Tarigan and Zetli (2022) applied BLOCPLAN in combination with CRAFT at a manufacturing facility and achieved significant MHC reductions. Muharni (2022) applied BLOCPLAN to a hot strip mill warehouse layout, demonstrating its applicability beyond discrete manufacturing. Sihombing et al. (2024) applied BLOCPLAN to tofu production, confirming its capacity for food processing industries. The current study extends this evidence to plantation commodity processing—specifically black tea CTC production—a context not previously documented in the BLOCPLAN literature.

A defining strength of BLOCPLAN relative to purely mathematical algorithms is its native support for visual block layout output, allowing researchers and management to directly inspect the spatial configuration of each candidate layout rather than interpreting only tabulated distance and cost figures. Ghozi and Hermanuadi (2023) emphasize that this visualization capability makes BLOCPLAN particularly effective for presentations to non-technical management audiences who may not be experienced in interpreting abstract algorithmic output. The current study leverages this characteristic by presenting both a scaled grid coordinate visualization and the final recommended floor plan of the BLOCPLAN LU5 layout, translating the algorithm's numerical output into an immediately interpretable spatial format for facility management decision-making.

Research Methods

Study Location and Object

This study was conducted at PT Perkebunan Nusantara 1 Regional 5 Wonosari Tea Plantation, located in Wonosari Village, Singosari District, Malang Regency, East Java, during August 2025. The research object was the physical configuration of 10 production departments within the black tea processing facility, with a total floor area of 1,120 m². The research employed a quantitative descriptive approach with computational engineering methods.

Data Collection

Three data collection methods were employed. First, direct observation and field measurement were conducted to obtain precise departmental dimensions, centroid coordinates for each of the 10 departments, and inter-departmental distances in the existing layout. Second, document review of internal company records—including the Operation Process Chart, routing sheets, existing facility layout drawings, and historical material transfer frequency logs—was performed to construct the From-To Chart (FTC), representing the quantitative inter-departmental material flow data required as BLOCPLAN input.

Third, structured interviews with field supervisors, foremen, and machine operators were conducted to establish qualitative departmental relationship priorities, formalized in the Activity Relationship Chart (ARC). The ARC encodes relationship values from A (Absolutely

Necessary proximity) through E, I, O, U, to X (Undesirable proximity). In this facility, A-type relationships were assigned to all sequential production pairs (D1–D2 through D9–D10), reflecting the mandatory adjacency of sequential CTC processing. X-type relationships were established between high-humidity departments (D1, D2) and dry processing departments (D6, D9) to prevent moisture contamination of finished tea products.

The unit cost per meter (IDR/m) for each material flow was derived from the facility's annual operational cost reports, disaggregated by handling equipment type. Three equipment categories were identified: (1) the monorail system serving the D1–D2 flow at IDR 1,566.09/m; (2) belt and roller conveyors at various rates, with the highest at IDR 59,009.41/m for the specialized D3–D4 screening conveyor; and (3) manual worker transport for certain movements. The wide range of unit costs—from IDR 961.63/m (D6–D7) to IDR 59,009.41/m (D3–D4)—underscores the importance of evaluating layout performance at the individual flow level, not only in aggregate.

Existing Layout Evaluation

The existing layout was evaluated by calculating the rectilinear distance between each pair of interacting departments using Equation (1), based on measured centroid coordinates of all 10 departments. The daily MHC for each of the nine material flows was computed using Equation (2). Total MHC and distance were aggregated to establish the baseline performance metrics against which all proposed layouts were compared.

BLOCPLAN Algorithm Application

The BLOCPLAN algorithm was executed using DosBox simulation software with dual input data comprising the FTC (quantitative flow matrix with 9 active inter-departmental flows) and the ARC (qualitative proximity matrix for all 10 department pairs). The algorithm generated 20 layout iterations (LU1 through LU20), from which the five layouts with the highest Adjusted R-Score values were selected for further MHC-based evaluation.

The best proposed layout was selected from these five by computing total MHC for each candidate layout using the same rectilinear distance and cost methodology applied to the existing layout. The layout yielding the lowest total MHC while also achieving the highest Adjusted R-Score was designated as the final proposed layout (LU5). The centroid coordinates of each department in LU5 were mapped from the BLOCPLAN block layout visualization, rescaled to actual facility dimensions, and used to calculate inter-departmental distances through Equation (1). A scaled departmental grid visualization and the final recommended floor plan were subsequently constructed to document the spatial configuration of the proposed layout for both technical verification and management presentation purposes.

Results and Discussion

Existing Facility Layout Analysis

The existing production facility at PTPN 1 Regional 5 Wonosari houses 10 departments spanning 1,120 m². The largest department is the Withering Room (D2) at 661 m², while the smallest are the Screening Department (D3) and the Organoleptic Laboratory (D8), each at 8 m². Measurement of all 9 active inter-departmental material flows revealed a total transfer distance of 360.7 meters and a total daily MHC of IDR 46,782,284.

Analysis of Table 1 reveals that the D1–D2 and D2–D3 flows together account for IDR 18,882,886 (40.36%) of total daily MHC despite comprising only 2 of 9 material flows. The D1–D2 flow is particularly critical: at 150 meters, it is more than double the second-longest flow (D2–D3 at 74.3 meters). Furthermore, the layout exhibits a critical backtracking pattern at D9–D10, where the Temporary Storage Department (D10) is positioned in the center of the facility, forcing material from the Packaging Department (D9) to travel backward across the active production area, adding 58 meters of unnecessary distance.

Table 1. Material Handling Cost (MHC) Matrix – Existing Layout

Material Flow	Distance (m)	Frequency/Day	Unit Cost (IDR/m)	Total MHC (IDR/Day)
D1 – D2	150.0	42	1,566.09	9,866,374.00
D2 – D3	74.3	24	5,056.37	9,016,512.00
D3 – D4	1.1	38	59,009.41	2,466,593.50
D4 – D5	9.8	225	2,237.27	4,933,187.00
D5 – D6	14.4	300	1,141.94	4,933,187.00
D6 – D7	11.4	450	961.63	4,933,187.00
D7 – D8	28.0	12	12,152.75	4,933,187.00
D7 – D9	13.7	48	3,750.90	2,466,593.50
D9 – D10	58.0	42	1,676.24	4,083,325.00
Total	360.7	—	—	46,782,284.00

Source: Primary data processed (2026)

BLOCPLAN LU5 Proposed Layout – Departmental Grid Visualization

Following BLOCPLAN algorithm execution with FTC and ARC inputs for the 10-department facility, 20 layout iterations were generated. The five with the highest Adjusted R-Score were selected for MHC-based evaluation. LU5 yielded both the highest Adjusted R-Score and the lowest total MHC among the five candidates—a convergence providing particularly strong justification for its selection. Figure 1 presents a scaled departmental grid visualization of the BLOCPLAN LU5 layout, mapping all 10 departments according to their centroid coordinates with block sizes proportional to floor area, and numbered flow paths labeled with actual LU5 distances.

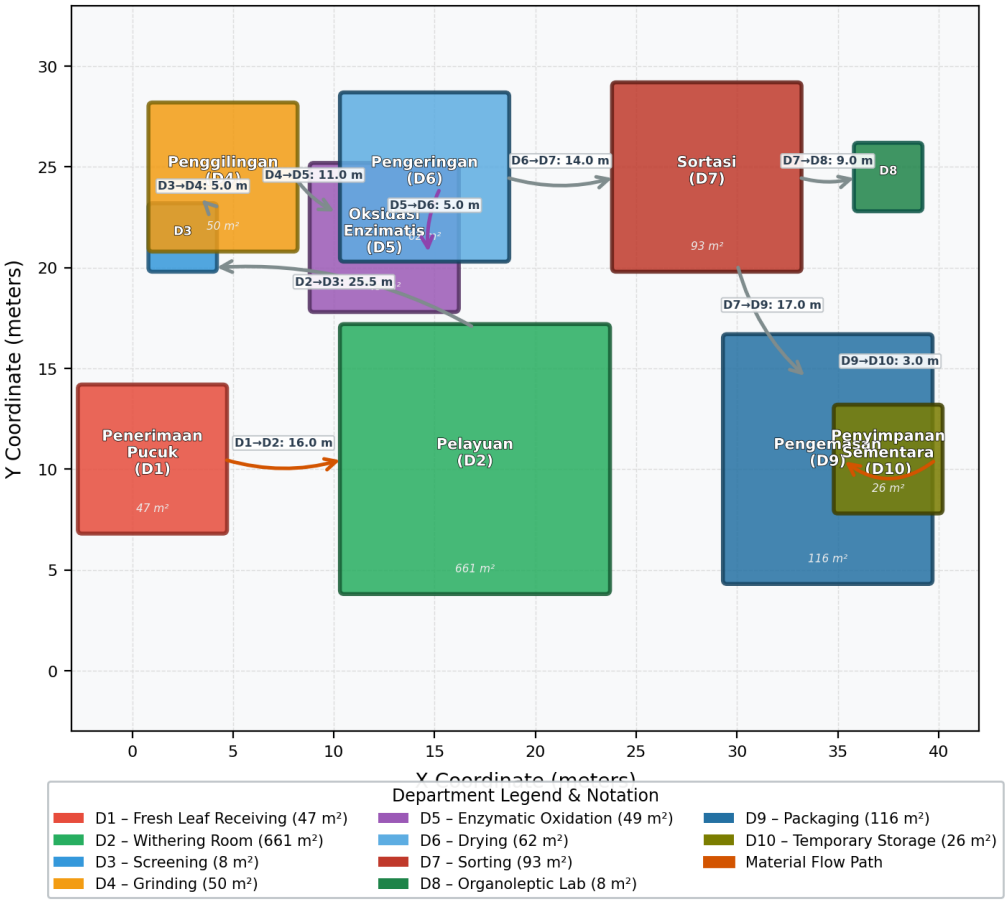


Figure 1. BLOCPLAN LU5 Proposed Layout – Departmental Grid Visualization
Source: Primary data processed (2026)

Figure 1 illustrates the fundamental structural change accomplished by BLOCPLAN LU5: the Withering Room (D2, 661 m²—the facility's largest department) is repositioned directly adjacent to the Fresh Leaf Receiving Department (D1), reducing the D1–D2 flow from 150 meters to just 16 meters. The layout also resolves the D9–D10 backtracking pattern by aligning the Packaging Department (D9) and Temporary Storage (D10) along the same horizontal band at the downstream end of the production sequence, reducing that flow from 58 meters to only 3 meters.

BLOCPLAN LU5 Departmental Coordinates

The centroid coordinates of each department in LU5, rescaled to actual facility dimensions, are presented in Table 2.

Table 2. Department Centroid Coordinates – BLOCPLAN LU5 Proposed Layout

No	Department	X Coordinate	Y Coordinate
1	D1 – Fresh Leaf Receiving	1.0	10.5
2	D2 – Withering	17.0	10.5
3	D3 – Screening	2.5	21.5
4	D4 – Grinding	4.5	24.5
5	D5 – Enzymatic Oxidation	12.5	21.5
6	D6 – Drying	14.5	24.5
7	D7 – Sorting	28.5	24.5
8	D8 – Organoleptic Lab	37.5	24.5
9	D9 – Packaging	34.5	10.5
10	D10 – Temporary Storage	37.5	10.5

Source: Primary data processed (2026)

BLOCPLAN LU5 Material Transfer Distance and MHC Calculation

Using the centroid coordinates in Table 2, the rectilinear distance between each pair of interacting departments was calculated. The resulting distance matrix and corresponding MHC values for all 9 material flows in the BLOCPLAN LU5 proposed layout are presented in Table 3.

Table 3. Material Transfer Distance and MHC Matrix – BLOCPLAN LU5 Proposed Layout

Material Flow	Distance (m)	Frequency/Day	Unit Cost (IDR/m)	Total MHC (IDR/Day)
D1 – D2	16.0	42	1,566.09	1,052,412.48
D2 – D3	25.5	24	5,056.37	3,094,498.44
D3 – D4	5.0	38	59,009.41	11,211,787.90
D4 – D5	11.0	225	2,237.27	5,537,243.25
D5 – D6	5.0	300	1,141.94	1,712,910.00
D6 – D7	14.0	450	961.63	6,058,269.00
D7 – D8	9.0	12	12,152.75	1,312,497.00
D7 – D9	17.0	48	3,750.90	3,060,734.40
D9 – D10	3.0	42	1,676.24	211,206.24
Total	105.5	—	—	33,251,558.71

Source: Primary data processed (2026)

BLOCPLAN LU5 Final Recommended Floor Plan

To complement the grid coordinate visualization and support direct implementation by facility management, the final recommended floor plan of the BLOCPLAN LU5 proposed layout is presented in Figure 2. This visualization translates the coordinate-based grid mapping in Figure 1 into a detailed spatial floor plan showing the actual physical arrangement recommended for implementation at PTPN 1 Regional 5.

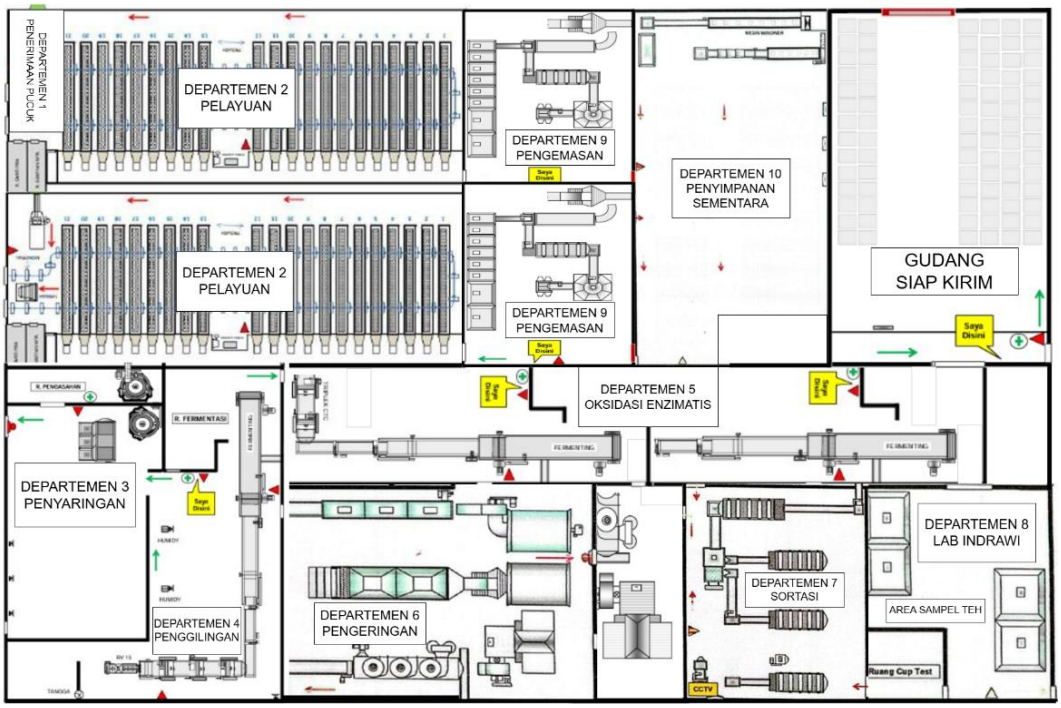


Figure 2. BLOCPLAN LU5 Final Recommended Floor Plan
Source: Cikal (2026)

Figure 2 provides the finalized spatial representation of the BLOCPLAN LU5 layout that was subsequently validated through Discrete Event Simulation and recommended for implementation. The floor plan confirms the structural repositioning identified in the grid coordinate analysis: the Withering Room is relocated adjacent to the Fresh Leaf Receiving Department, and the Packaging and Temporary Storage departments are aligned to eliminate backtracking, together forming a layout configuration that closely follows the sequential logic of the CTC production process from raw material receiving through to finished product storage.

Comparative Analysis: Existing Layout vs. BLOCPLAN LU5

A direct per-flow comparison between the existing layout and the BLOCPLAN LU5 proposed layout provides a comprehensive evaluation of the efficiency improvements achieved through the redesign. Table 4 presents this side-by-side comparison for all 9 material flows, covering both transfer distance (meters) and daily MHC (IDR/day).

The comparative analysis in Tables 4 and 5 reveals that the BLOCPLAN LU5 proposed layout achieves a total transfer distance of 105.5 meters, representing a 70.75% reduction from the existing 360.7 meters, and a total daily MHC of IDR 33,251,558.71, representing a 28.89% reduction from the existing IDR 46,782,284—a daily cost saving of IDR 13,530,725.29.

The most transformative individual flow improvement is the D1–D2 path, which is reduced from 150 meters to 16 meters, an 89.33% reduction corresponding to a daily MHC saving of IDR 8,813,961.52 from this single flow alone. This improvement is not merely incremental but structural, as visually confirmed in Figures 1 and 2: by positioning the Withering Room (D2) immediately adjacent to the Fresh Leaf Receiving Department (D1), the monorail travel time per trip is reduced from 300 seconds to 32 seconds (16 m ÷ 0.5 m/s). This eliminates the primary bottleneck that previously caused the monorail transport system to

operate at full utilization (99%) while accumulating a queue of 7,131 unprocessed entities in simulation modeling (Cikal, 2026).

Table 4. Per-Flow Comparison: Existing Layout vs. BLOCPLAN LU5 Proposed Layout

Material Flow	Existing Distance (m)	LU5 Distance (m)	Distance Δ (%)	Existing MHC (IDR/Day)	LU5 MHC (IDR/Day)	MHC Δ (%)
D1–D2	150.0	16.0	↓ 89.33%	9,866,374.00	1,052,412.48	↓ 89.33%
D2–D3	74.3	25.5	↓ 65.68%	9,016,512.00	3,094,498.44	↓ 65.68%
D3–D4	1.1	5.0	↑ 354.5%	2,466,593.50	11,211,787.90	↑ 354.5%
D4–D5	9.8	11.0	↑ 12.24%	4,933,187.00	5,537,243.25	↑ 12.24%
D5–D6	14.4	5.0	↓ 65.28%	4,933,187.00	1,712,910.00	↓ 65.28%
D6–D7	11.4	14.0	↑ 22.81%	4,933,187.00	6,058,269.00	↑ 22.81%
D7–D8	28.0	9.0	↓ 67.86%	4,933,187.00	1,312,497.00	↓ 73.41%
D7–D9	13.7	17.0	↑ 24.09%	2,466,593.50	3,060,734.40	↑ 24.09%
D9–D10	58.0	3.0	↓ 94.83%	4,083,325.00	211,206.24	↓ 94.83%
Total	360.7	105.5	↓ 70.75%	46,782,284.00	33,251,558.71	↓ 28.89%

Source: Primary data processed (2026)

The D9–D10 flow achieves the single largest percentage distance reduction at 94.83% (from 58 meters to 3 meters), directly eliminating the backtracking pattern where finished tea had to travel from the Packaging Department backward through the production area to reach Temporary Storage—a resolution clearly visible in the aligned D9–D10 placement shown in both Figure 1 and Figure 2. The D2–D3 flow is reduced from 74.3 meters to 25.5 meters (65.68%), substantially improving the second-most costly flow in the existing layout.

Table 5. Summary Comparison: Existing Layout vs. BLOCPLAN LU5 Proposed Layout

Performance Metric	Existing Layout	BLOCPLAN LU5	Reduction (%)
Total Transfer Distance (m)	360.7	105.5	70.75%
Total Daily MHC (IDR)	46,782,284.00	33,251,558.71	28.89%
Daily MHC Savings (IDR)	—	—	13,530,725.29

Source: Primary data processed (2026)

It is important to acknowledge that four material flows—D3–D4, D4–D5, D6–D7, and D7–D9—experience distance increases under the BLOCPLAN LU5 configuration (see Table 4). However, these increases are economically modest: the combined additional MHC from these four flows amounts to IDR 3,069,466.05 per day, which is overwhelmingly offset by the IDR 16,600,191.34 daily savings generated by the five flows that improve (D1–D2, D2–D3, D5–D6, D7–D8, and D9–D10). This trade-off is entirely justified from a system optimization perspective, as the BLOCPLAN algorithm prioritizes global optimality over local individual flow minimization (Hadiputri et al., 2022).

The D3–D4 flow warrants specific discussion: despite its distance increasing from 1.1 meters to 5.0 meters, its contribution to total MHC increases from IDR 2,466,593.50 to IDR 11,211,787.90—the largest absolute MHC increase among any flow in the proposed layout. This is attributable to the extremely high unit cost for the D3–D4 handling equipment (IDR 59,009.41/meter), which amplifies the impact of even small distance changes. Management should therefore consider whether additional modifications could minimize the D3–D4 distance in future iterations, or whether the handling cost for this specific flow can be reduced through equipment substitution.

This result illustrates an important principle for facility layout decision-making: total distance reduction and total MHC reduction are not equivalent metrics and should not be used interchangeably. A layout that achieves large distance reductions on low-cost flows while increasing distances on high-cost flows may produce a smaller MHC improvement than the distance metric suggests. The 70.75% distance reduction versus 28.89% MHC reduction observed in this study is a direct consequence of the D3–D4 cost amplification effect—a nuance that per-flow analysis reveals and aggregate analysis conceals.

Overall, the BLOCPLAN LU5 proposed layout, as visually documented in Figures 1 and 2, demonstrates that restructuring the departmental configuration based on the dual criteria of material flow cost (FTC) and qualitative relationship priority (ARC) generates a net system improvement that would not be achievable through sequential pairwise optimization alone. The alignment of D1, D2, D9, and D10 along a single horizontal band in LU5 reflects BLOCPLAN's capacity to recognize and enforce the flow-dominant structure of CTC black tea processing, where the early-stage (D1–D2) and late-stage (D9–D10) material flows impose the highest cost burden per distance unit.

From a practical implementation standpoint, the visual documentation in Figures 1 and 2 provides facility management with an immediately interpretable basis for phased implementation planning. The D1–D2 repositioning alone—moving the Withering Room adjacent to Fresh Leaf Receiving—generates IDR 8,813,961.52 in daily MHC savings, making it the single highest-return relocation action available and the most visually prominent structural change in Figure 2. If implemented in isolation as a first phase, this single change would already reduce total daily MHC by 18.84% without requiring any other departmental movements, providing management with a low-risk, high-return entry point into the broader layout redesign program.

Conclusion

This study applied the BLOCPLAN hybrid facility layout algorithm to redesign the black tea production facility at PT Perkebunan Nusantara 1 Regional 5 Wonosari Tea Plantation with the objective of minimizing material transfer distance and daily Material Handling Cost (MHC). The BLOCPLAN algorithm, processing dual inputs from the From-To Chart (FTC) and Activity Relationship Chart (ARC), generated 20 layout iterations, from which the layout designated LU5 was selected based on its highest Adjusted R-Score and lowest total MHC.

The proposed BLOCPLAN LU5 layout achieved a total material transfer distance of 105.5 meters—a 70.75% reduction from the existing 360.7 meters—and a total daily MHC of IDR 33,251,558.71, representing a 28.89% reduction from the existing IDR 46,782,284 and a daily cost saving of IDR 13,530,725.29. The most significant individual improvement was the D1–D2 flow, reduced from 150 meters to 16 meters (89.33%), eliminating the primary production bottleneck. The D9–D10 backtracking pattern was also fully eliminated, reducing the Packaging-to-Temporary Storage flow from 58 meters to 3 meters (94.83%). Per-flow analysis revealed that the divergence between aggregate distance reduction (70.75%) and aggregate MHC reduction (28.89%) is driven by the high unit cost of the D3–D4 handling equipment (IDR 59,009.41/m), which amplifies a modest distance increase on that flow into a substantial MHC increase.

The scaled departmental grid visualization and final recommended floor plan presented in this study provide facility management with an immediately interpretable spatial reference for implementation, translating BLOCPLAN's numerical output into an actionable redesign blueprint. These findings confirm that BLOCPLAN's hybrid approach—simultaneously optimizing quantitative material flow costs and qualitative departmental relationship priorities—is highly effective for facility layout redesign in complex agricultural commodity processing environments. Future research is recommended to integrate ergonomic and occupational health factors into the layout evaluation criteria, and to explore advanced

metaheuristic algorithms such as Genetic Algorithm or Simulated Annealing as performance benchmarks against BLOCPLAN in this industrial context.

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