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Improving the Layout of Production Facilities Using the Systematic Layout Planning and BLOCPLAN Algorithm

Filscha Nurprihatin*[1], Jordy[2], Glisina Dwinoor Rembulan[3], Ivana Tita Bella Widiwati[1], Ali Vaezi[4]
[1]Department of Industrial Engineering, Sampoerna University, L'Avenue Building, Jl. Raya Pasar Minggu No. Kav. 16, Pancoran, South Jakarta 12780, Indonesia
[2]Department of Industrial Engineering, Universitas Bunda Mulia, Jl. Lodan Raya No. 2, Pademangan, North Jakarta 14430, Indonesia
[3]Department of Management, Universitas Bunda Mulia, Jl. Lodan Raya No. 2, Pademangan, North Jakarta 14430, Indonesia
[4]Department of Logistics and Supply Chain Management, Trent University, L1J 5Y1, Canada
e-mail: *[1]**filscha.nurprihatin@sampoernauniversity.ac.id**, [2]jordysurya82@gmail.com, [3]grembulan@bundamulia.ac.id, [1]ivana.widiwati@my.sampoernauniversity.ac.id, [4]alivaezi@trentu.ca

*Corresponding: filscha.nurprihatin@sampoernauniversity.ac.id

ABSTRACT

The research focuses on resolving production floor problems which affect an electronics manufacturing facility that produces stabilizers and starters and casings by using a job-shop production system. The lack of structured layout design has caused materials to travel through long routes which also require multiple returns across all three product manufacturing lines. The facility layout received its redesign through Systematic Layout Planning (SLP) and the BLOCPLAN algorithm. The research team used From-to Chart (FTC) and Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD) and Space Relationship Diagram (SRD) tools to develop three different layouts which they assessed by measuring total distance and backtracking distance and backtracking percentage. Proposed Layout 3 achieved better results than the original layout by reducing material movement distance by 36.35 meters and backtracking distance by 25.08 meters and backtracking percentage by 7.73 percent which showed the value of the SLP–BLOCPLAN framework for multi-product manufacturing facilities.

Keywords: *Facility Layout Planning, Systematic Layout Planning, BLOCPLAN Algorithm, Material Flow Optimization, Backtracking Reduction, Job Shop Manufacturing*

INTRODUCTION

The worldwide manufacturing industry faces growing competition because customers want more products and technology moves forward at a fast rate which forces companies to improve their production operations and their resource management (Nurprihatin, Elvina, et al., 2021; Nurprihatin, Gotami, et al., 2021). The market has become more unstable which forces manufacturers to produce superior products at reasonable prices while they need to keep their production systems flexible (Nurprihatin et al., 2022). A study recognized strategic levers which combine price–quality differentiation with consumer rebate systems to form linked demand-side mechanisms (Majumder et al., 2025). However, the production system needs to run at its best for their extended success to become possible (Majumder et al., 2025). Consequently, Businesses need supply-side optimization through organized facility layout design to achieve long-term manufacturing competitive advantages.

The design of production facilities determines how materials move through the system while defining the distance between stations and the production speed and employee work performance. The wrong layout design will force materials to move in ways that create useless handling operations while they follow opposing paths to main production lines which results in higher operational expenses and delivery problems (Laomongkholchaisri et al., 2024; Salins et al., 2024). The design of a layout which places elements strategically in space creates better workflow efficiency and higher employee satisfaction because it shortens unnecessary travel and provides easier access (Li et al., 2023; Zamani et al., 2024). The manufacturing industry needs to keep improving its production facility design because this process will increase both manufacturing efficiency and environmental protection standards.

Three main types of factory layout planning exist which include greenfield planning for new facilities and brownfield planning for existing plant modifications and unutilized facility revitalization (Klar et al., 2022). The planning process works toward specific objectives through its organized structure which follows a planned order of stages that integrate production cycle limitations (Klar et al., 2022). The research team uses brownfield planning methods to transform the existing production space which remains operational. The Systematic Layout Planning (SLP) method which started as a phase-based system solves the problems of intuitive plant design by using numerical and non-numerical facility distance data to produce and assess different layout options (Egbukichi et al., 2026; Jasrotia & Sengottaiyan, 2024). The manufacturing system achieves cost efficiency through its established layout which supports dependable operations and flexible production methods (Rodriguez et al., 2023).

Multiple business sectors have confirmed through their own experiences that the fundamental SLP tools produce effective results which include the From-to Chart (FTC), Activity Relationship Chart (ARC), Activity Relationship Diagram (ARD), and Space Relationship Diagram (SRD). A research study showed that hospital laundry facilities achieved 37.69% and 35.88% material movement reductions through the use of FTC and ARC (Laomongkholchaisri et al., 2024), while another study combined FTC with SRD to improve food processing production plants (Teneda et al., 2023). The research team applied all SLP tools to a chemical fertilizer plant which resulted in better logistics operations and improved plant space management (Huang et al., 2025). Prior research conducted validation through two methods which include simulation-based layout assessment and hospital facility design using Mixed-Integer Programming and multi-criteria facility evaluation through MARCOS (Boonmee et al., 2022; Cubukcuoglu et al., 2022; Gölcük et al., 2022).

The SLP toolkit proves to be an essential tool because evidence from manufacturing and logistics environments demonstrates its value. A previous study showed that their ARD and SRD guided redesign methods improved area utilization by 30% and material flow rate by 20% (Kumar & Malleswari, 2022). Another paper established a detailed multi-criteria layout selection system through their combination of ARC and SRD and TOPSIS methods for turbine repair workshop design (Cáceres-Gelvez et al., 2022). SRD has further been applied as a correlation-based location relationship diagram in logistics center design (Li, 2023). The adaptation of SLP with an Industry 4.0 approach demonstrated a 16.84% efficiency improvement in a manufacturing laboratory setting (Rodriguez et al., 2023). Table 1 summarizes key related works and their respective SLP tool applications, contextualizing the methodological contribution of the present study.

In addition to SLP tools, the BLOCPLAN algorithm—a graph-theoretic method for generating block layouts from adjacency graphs—has been applied to minimize inter-facility distances and maximize proximity-based relationships (Tamer et al., 2023). BLOCPLAN iteratively evaluates candidate layouts using adjacency scores, r-scores, and rail-distance scores to identify near-optimal configurations, producing 12 alternative layouts with efficiencies ranging from 48.91% to 73.91% in a shipyard facility case study (Tamer et al., 2023). Furthermore, a paper demonstrated that integrating ARC with BLOCPLAN in warehouse material handling achieved a 52% reduction in operational costs. Despite these results, the combined application of the full SLP toolkit with BLOCPLAN in electronics manufacturing—a sector characterized by multi-product job shop complexity—remains insufficiently examined in the existing literature (Nurmutia, 2024).

Table 1. Related Works

Authors	Systematic Layout Planning Tools					Objectives
	FTC	ARC	ARD	SRD	BLOCPLAN Algorithm	
(Laomongkholchaisri et al., 2024)	✓	✓				Minimize material movement distance in hospital laundry facility layout.
(Teneda et al., 2023)	✓			✓		Optimize the plant layout of a blackberry pulp production process.
(Huang et al., 2025)		✓	✓	✓		Optimize fertilizer plant layout to reduce logistics intensity and costs.
(Nurmutia, 2024)		✓			✓	Improve warehouse material handling efficiency and reduce operational costs.
This Paper	✓	✓	✓	✓	✓	Improve electronics manufacturing layout using integrated SLP–BLOCPLAN.

The paper The current research solves this research gap by using a combined SLP–BLOCPLAN system to create new production floor designs for an electronics manufacturing company which produces stabilizers and starters and casings. The current layout system operates without material flow analysis which results in long travel distances between stations and multiple instances of workers needing to backtrack. The primary objective is to develop and evaluate alternative facility layouts that minimize material movement distances and backtracking percentage, thereby enhancing production efficiency and reducing non-value-added activities. This study establishes new benchmarks by evaluating different proposed layouts through three distinct performance measures which include total distance and backtracking distance and backtracking percentage. This study employs a comparative approach which previous facility layout studies have not fully explored.

METHODS

The research team began their work by watching production activities on the factory floor while they conducted interviews with staff members at the plant to find out about operational problems and what caused them. The research team gathered three main sets of data which included the first facility layout design and the production process routes for stabilizer and starter and casing products and the movement patterns of materials between stations. The research team gathered these data through company documents and by conducting field-based measurement activities. The research team established thirteen workstations which they identified as stations A through M while they established rectangular points to calculate straight-line distances between stations for assessing baseline and proposed layouts based on distance and backtracking performance.

The research team executed the SLP methodology after they obtained their data through a step-by-step analysis which the research flowchart (Figure 1) describes. The FTC structure enables stations to measure their material transfer amounts and it shows which pathways serve as main transportation routes for their entire product range. The ARC received its initial development for every product category through which it created qualitative similarity scores which it now calls Absolute (A), Especially Important (E), Important (I), Ordinary (O), and Unimportant (U) to evaluate all facility pairings. The ARD converted ARC proximity data into a spatial adjacency diagram which SRD used to display actual area needs for every workstation. The tools provided organized data which helped me develop new facility layout options by placing facilities with strong connection scores together to reduce their material transportation needs and their need to revisit previous stops.

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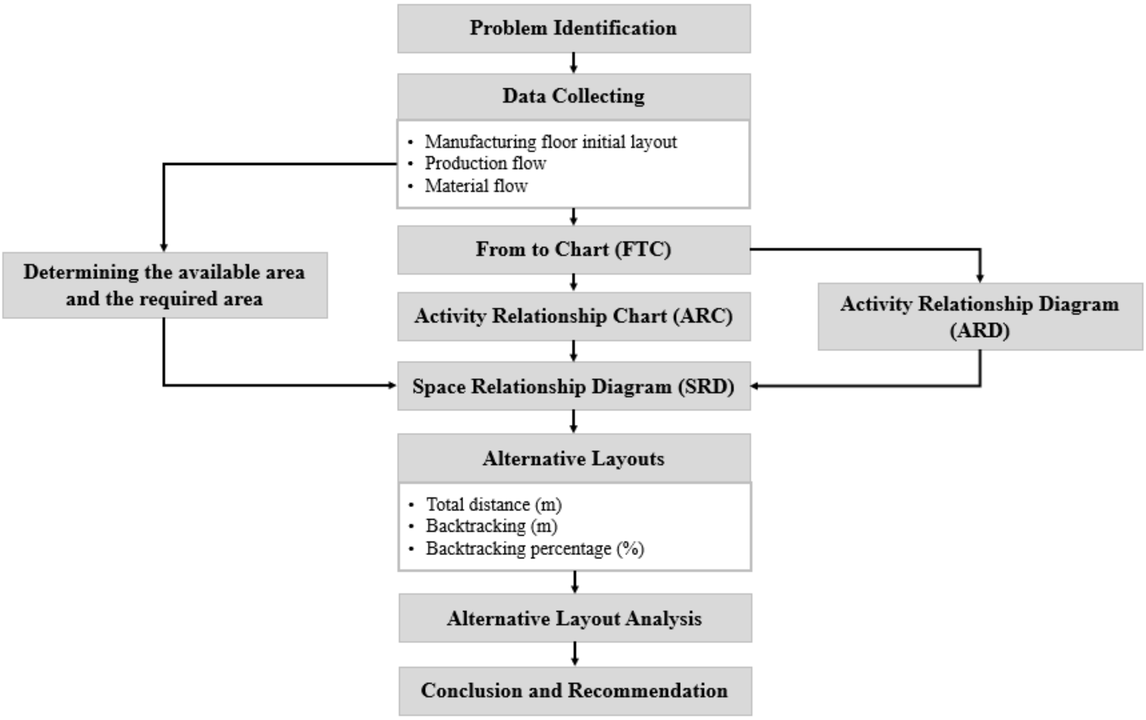

Figure 1. Research Flow Chart

The development of alternative facility layouts emerged through two systems which combined SLP-directed spatial organization with the BLOCPLAN operational algorithm. The BLOCPLAN algorithm developed various layout options for every product type through an iterative computational process which produced five different options for each product. The evaluation process for these alternatives used three scoring criteria which consisted of adjacency score and r-score and rail-distance score to find the best layout for each product line. The BLOCPLAN layouts which the team selected for stabilizer and starter and casing products merged into one multi-product layout through multiple trial-and-error processes which produced three final layout proposals. The evaluation process for each suggested layout involved calculating the full distance of material movement together with backtracking distance and backtracking percentage for three product categories. The evaluation process used the starting layout as a reference point to determine how much the new layouts would perform better.

RESULTS AND DISCUSSION

The analysis of material flow revealed nine separate paths which operated through thirteen different workstations to cover all three product lines. Table 2 shows that both stabilizer and starter products use the same sequence of stations for close casing and bottom casing components (A→E→D→C→M→L→K or J). The processing paths of transformer components and starter machine components and stabilizer machine components operate independently through their own abbreviated routes. The recorded workstation points in Table 3 enabled researchers to determine the distances between stations through straight-line measurements between the recorded points. The company needs a data-based system to create new layouts because their nine product materials follow different paths which increase their production system complexity.

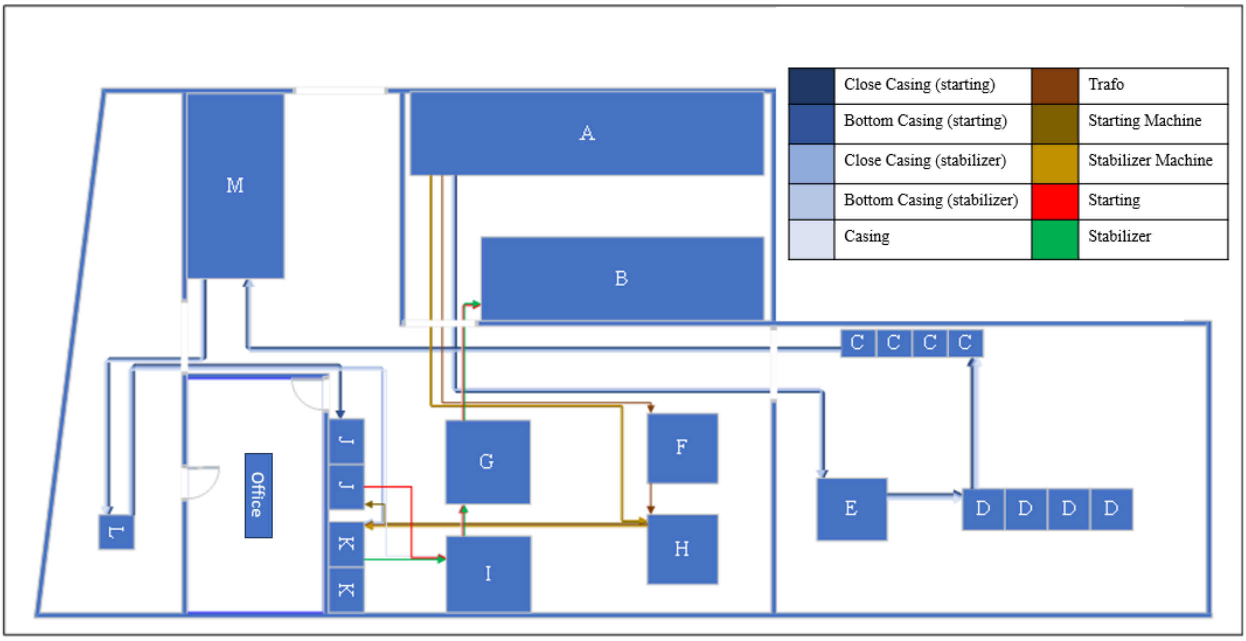

Figure 2. Factory layout and material flow

Table 2. Material Flow

Material	Process Flow Between Stations
Close Casing (starter)	A, E, D, C, M, L, J
Bottom Casing (starter)	A, E, D, C, M, L, J
Close Casing (stabilizer)	A, E, D, C, M, L, K
Bottom Casing (stabilizer)	A, E, D, C, M, L, K
Trafo	A, F, H, K
Starter Machine	A, H, J
Stabilizer Machine	A, H, K
Stabilizer	K, I, G, B
Starter	J, I, G, B

Table 3. Work Station Coordinate Point

No	Station	X-coordinate (m)	Y-coordinate (m)
1	A	15,5	13,8
2	B	16,5	9,7
3	C	24,7	7,8
4	D	28,5	3,1
5	E	23,0	3,1
6	F	18,2	4,8
7	G	12,7	4,5
8	H	18,2	1,9
9	I	12,7	1,25
10	J	8,7	4,4
11	K	8,7	1,4
12	L	2,2	2,4
13	M	5,6	12,4

ARC were constructed for all three product types to establish proximity requirements between workstation pairs (Figures 3–5). For stabilizer products, the ARC identified seven absolute (A) relationships warranting the closest possible proximity, including pairings such as raw materials with finished goods, plate bending with punch machine stations, and quality control with the stabilizer assembly station (Figure 3). The distribution comprised seven A, six Especially Important (E), seven Important (I), seven Ordinary (O), and 41 Unimportant (U) relationships. The starter ARC (Figure 4) similarly identified seven absolute relationships, including quality control–assembly starter and screen printing–paint station adjacencies, with three E, four I, four O, and 36 U relationships. The casing ARC (Figure 5) yielded six absolute relationships—notably omitting the quality control–assembly interface absent from the casing process—with one E, three I, two O, and 24 U relationships.

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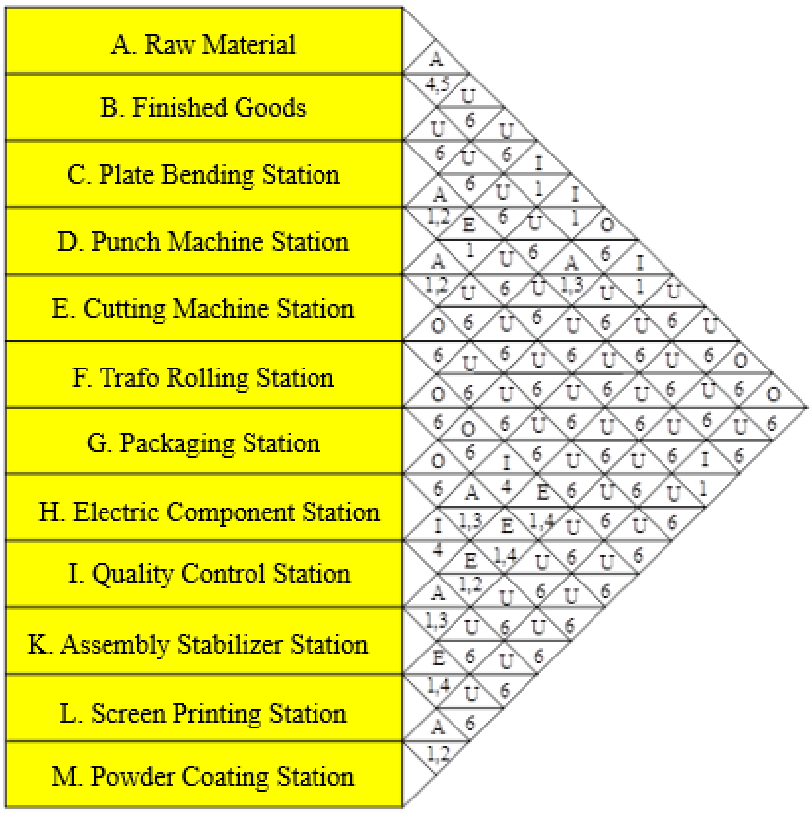

Figure 3. ARC Stabilizer

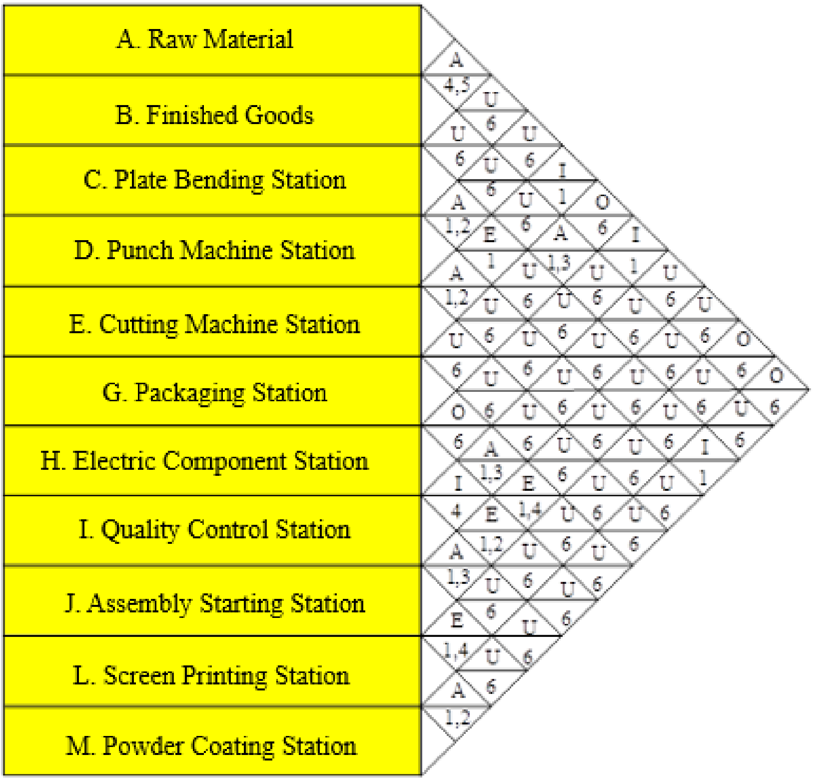

Figure 4. ARC Starter

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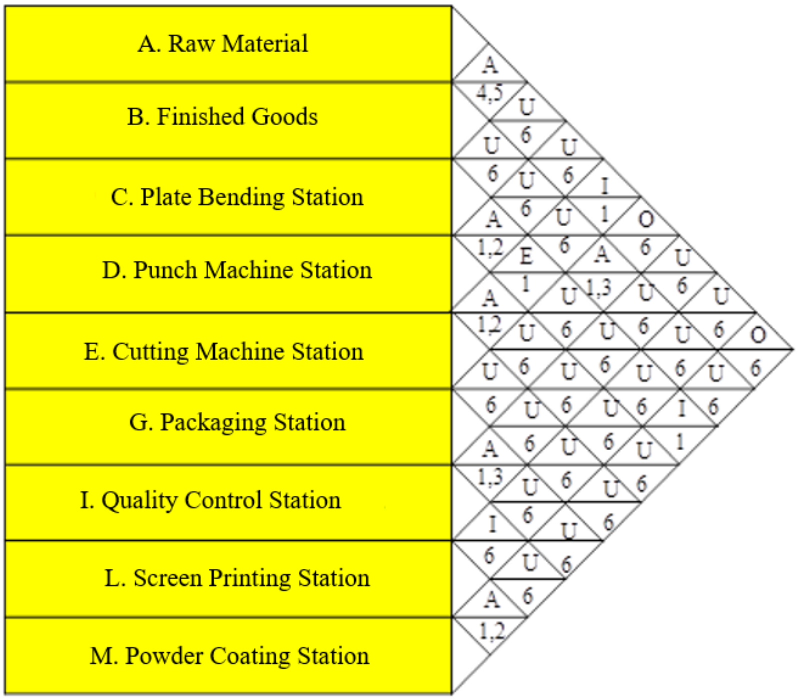

Figure 5. ARC Casing

The first layout analysis demonstrated that all three product lines operated with major operational problems which Table 4 shows. The stabilizer production process recorded the greatest total inter-station distance at 219.20 m, followed by starter production at 201.60 m and casing at 102.15 m. The starter process showed backtracking through a total counter-flow distance of 91.20 meters but casing production demonstrated the highest percentage of backtracking at 58.98% which means most casing material movements went against the main flow direction. The values show that the original design produced non-value-added handling operations which spread across all three product lines because it did not use established material flow analysis techniques. The first set of layout details creates a detailed numerical framework which allows for assessment of various implemented alternative design options.

The development of Proposed Layout 1 used SLP-based spatial planning to create workstation layouts which followed ARC-based proximity standards and SRD-based area restrictions. The layout demonstrated the most significant decrease in total material movement distance which reached 40.18 meters when averaged across three different product types. The stabilizer and starter processes showed the highest reduction in movement distance because they decreased by 61.40 meters and 61.00 meters respectively. The casing process showed a small increase of 1.85 meters in distance because of the geometric changes which resulted from combining three product flows into one complete layout. The backtracking distance reduced by 21.32 meters while backtracking percentage dropped by 3.73%. The data shows that Proposed Layout 1 brings an important improvement which affects both statistical results and operational performance when compared to the original baseline setup.

Table 4. Initial Layout Data Processing Results

Parameter	Product	Initial Layout
Distance (m)	Stabilizer	219,20
	Starter	201,60
	Casing	102,15
Backtracking (m)	Stabilizer	86,20
	Starter	91,20
	Casing	60,25
Backtracking percentage (%)	Stabilizer	39,32
	Starter	45,24
	Casing	58,98

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Table 5. Proposed Layout 1 vs. Initial Layout

Parameter	Product	Initial Layout	Proposed Layout 1	Difference	Average
Total distance (m)	Stabilizer	219,20	157,80	61,40	40,18
	Starter	201,60	140,60	61,00	
	Casing	102,15	104,00	-1,85	
Backtracking (m)	Stabilizer	86,20	58,60	27,60	21,32
	Starter	91,20	61,70	29,50	
	Casing	60,25	53,40	6,85	
Backtracking percentage (%)	Stabilizer	39,32	37,14	2,19	3,73
	Starter	45,24	43,88	1,35	
	Casing	58,98	51,35	7,64	

Table 6. Proposed Layout 2 vs. Initial Layout

Parameter	Product	Initial Layout	Proposed Layout 2	Difference	Average
Total distance (m)	Stabilizer	219,20	193,70	25,50	36,28
	Starter	201,60	153,70	47,90	
	Casing	102,15	66,70	35,45	
Backtracking (m)	Stabilizer	86,20	59,90	26,30	26,22
	Starter	91,20	62,10	29,10	
	Casing	60,25	37,00	23,25	
Backtracking percentage (%)	Stabilizer	39,32	30,92	8,40	5,58
	Starter	45,24	40,40	4,83	
	Casing	58,98	55,47	3,51	

Table 7. Proposed Layout 3 vs. Initial Layout

Parameter	Product	Initial Layout	Proposed Layout 3	Difference	Average
Total distance (m)	Stabilizer	219,20	160,80	58,40	36,35
	Starter	201,60	141,50	60,10	
	Casing	102,15	111,60	-9,45	
Backtracking (m)	Stabilizer	86,20	52,50	33,70	25,08
	Starter	91,20	56,90	34,30	
	Casing	60,25	53,00	7,25	
Backtracking percentage (%)	Stabilizer	39,32	32,65	6,68	7,73
	Starter	45,24	40,21	5,03	
	Casing	58,98	47,49	11,49	

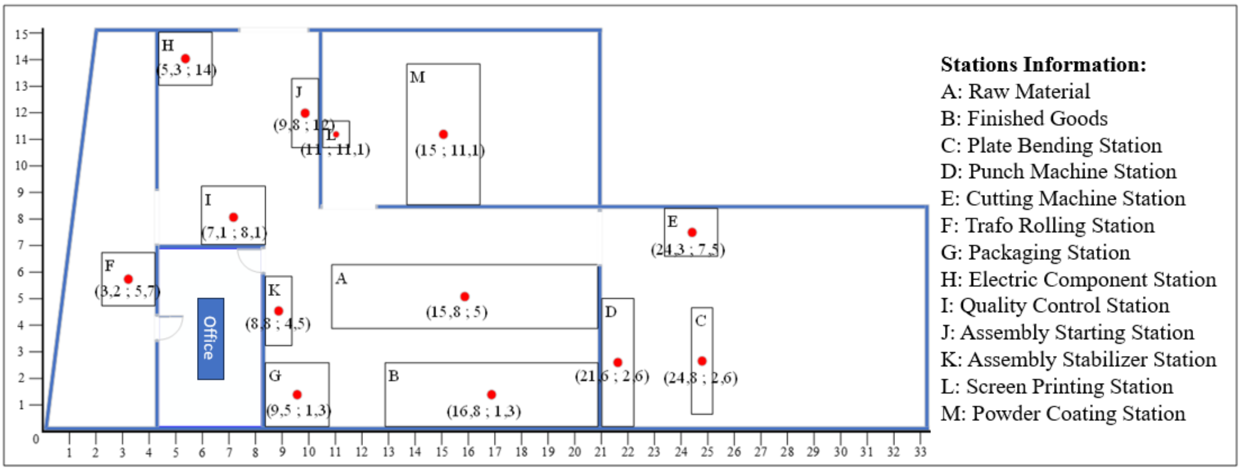

Figure 6. Proposed Layout 3 – Selected Configuration

Table 8. Comparison of Overall Average Difference of Proposed Layouts

Parameter	**Proposed Layout 1**		**Proposed Layout 2**		**Proposed Layout 3**	
	Average Decrease Difference	**Rank**	**Average Decrease Difference**	**Rank**	**Average Decrease Difference**	**Rank**
Total distance (m)	40,18	1	36,28	3	36,35	2
Backtracking (m)	21,32	3	26,22	1	25,08	2
Backtracking percentage (%)	3,73	3	5,58	2	7,73	1

This paper developed Proposed Layout 2 through BLOCPLAN system choices which they combined into one complete architectural arrangement. Table 6 shows that this design arrangement decreased total travel distance by 36.28 meters which stands below the performance of Proposed Layout 1. The system achieved its highest backtracking distance reduction by 26.22 meters when processing all three products. The system showed backtracking distance reductions which reached 26.30 meters for stabilizer production and 29.10 meters for starter production and 23.25 meters for casing production. The average backtracking percentage decreased by 5.58%. The research findings show that Proposed Layout 2 creates better material flow direction alignment through its spatial design although it needs two extra feet of total distance traveled which reflects the standard trade-off between these two performance elements in multi-product layout design.

The design of Proposed Layout 3 which appears in Figure 6 includes two additional workstations that function as the stabilizer assembly station and the transformer winding station to support all three product lines through one complete system. The design followed BLOCPLAN results which showed the starter production process but further development occurred through multiple cycles of testing and adjustment. Table 7 demonstrates that Proposed Layout 3 reduced total distance by 36.35 meters which represents a small improvement over Proposed Layout 2. More significantly, The system achieved its best performance through a backtracking percentage drop of 7.73% which applied to all three product lines with specific results of 6.68% for stabilizer and 5.03% for starter and 11.49% for casing. The casing process required an additional 9.45 meters of travel distance because the team decided to accept this geometric adjustment to achieve better backtracking results.

The three proposed layouts received different performance scores which showed their individual strengths through the comparative ranking system presented in Table 8. The first layout design achieved the best results in minimizing total travel distance with an average of 40.18 meters. The second layout design achieved the best results in backtracking distance reduction with an average of 26.22 meters. The third layout design achieved the best results in backtracking percentage reduction with an average of 7.73%. The operational value of backtracking percentage stands as the most critical metric because it shows what percentage of material movement becomes wasteful operation when compared to the complete material movement volume. The system achieves its directional efficiency because this measurement stands alone and uses a direct scale to determine how much value-added processing exists in the material flow. The research team identified Proposed Layout 3 as the best configuration through their assessment. All three proposed layouts demonstrated measurable superiority over the initial layout across at least two of the three parameters, confirming the validity of the analytical framework.

The results of this study align with and substantively extend findings reported in the facility layout literature. The 7.73% average backtracking percentage reduction and 36.35 m average total distance reduction achieved by the selected layout are consistent with improvements documented by the prior studies which reported distance reductions of 35.88%–37.69% and 34% using SLP-based approaches (Laomongkholchaisri et al., 2024; Salins et al., 2024). The effectiveness of BLOCPLAN in generating viable alternative configurations corroborates findings (Nurmutia, 2024; Tamer et al., 2023). The present study advances the literature by demonstrating that the integrated SLP–BLOCPLAN framework successfully addresses multi-product job shop complexity—a manufacturing context significantly more constrained than the single-product facilities examined in the majority of prior studies. Future research should incorporate simulation-based validation and demand variability scenarios to further substantiate the dynamic performance of the proposed layout under realistic operating conditions.

CONCLUSIONS

This study applied Systematic Layout Planning and the BLOCPLAN algorithm to redesign the production floor layout of an electronics manufacturer operating a multi-product job shop. Activity Relationship Chart analysis established the following proximity relationship distributions: the stabilizer process comprised seven Absolute (A), six Especially Important (E), seven Important (I), seven Ordinary (O), and 41 Unimportant (U) relationships; the starter process comprised seven A, three E, four I, four O, and 36 U relationships; and the casing process comprised six A, one E, three I, two O, and 24 U relationships. These proximity specifications, in conjunction with the FTC, ARD, and SRD outputs, constituted the structured input for subsequent layout generation via both SLP spatial arrangement and the BLOCPLAN algorithm.

Three alternative layouts were developed and evaluated across three performance parameters. Proposed Layout 1 achieved the greatest average total distance reduction of 40.18 m; Proposed Layout 2 yielded the highest average backtracking distance reduction of 26.22 m; and Proposed Layout 3 attained the highest average backtracking percentage reduction of 7.73%. The research team selected Proposed Layout 3 as the best design through their comprehensive evaluation which used backtracking percentage as the main indicator to measure directional efficiency of layouts because it operates independently of scale and shows exactly how much value-added processing occurs in material flow. The implementation of three new layout proposals showed better results than the first design which proved the integrated SLP–BLOCPLAN system operates effectively for manufacturing multiple products in production environments.

The research study contains various constraints which need to be recognized. The evaluation took place during fixed production operations which did not consider how changing customer demands and equipment failures and unpredictable staff availability would affect actual facility arrangements. The process of merging product-specific BLOCPLAN layouts through trial-and-error does not produce an optimal solution which works for all products in a multi-product configuration. Research needs to continue through simulation-based validation studies which will verify dynamic facility layout performance under realistic operating scenarios. The application of metaheuristic algorithms which combine genetic algorithms with reinforcement learning-based layout planners (Klar et al., 2022) will work as a support system for SLP and BLOCPLAN to identify more solutions during multi-objective facility layout optimization.

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