Flanş Üretim Tesislerinde Tesis Yerleşimi ve Üretim Planlama Kararlarının Optimizasyonu: CRAFT ve CORELAP Algoritmalarının Uygulanması

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Araştırma Makalesi

ÖZ

Verimli tesis yerleşim planlaması, iş akışını optimize etmek, malzeme taşıma maliyetlerini azaltmak ve üretim verimliliğini artırmak için gereklidir. Flanş üretiminde, etkin olmayan yerleşim planları nakliye maliyetlerinin artmasına ve üretim verimsizliklerine yol açar. Sistematik yerleşim optimizasyonu stratejilerinin uygulanması, rekabet gücünün ve maliyet etkinliğinin korunması için çok önemlidir. Bu çalışma, CRAFT (Tesislerin Bilgisayarlı Göreceli Tahsis Tekniği) ve CORELAP (Bilgisayarlı İlişki Düzen Planlaması) algoritmalarını kullanarak tesis yerleşimlerinin optimizasyonunu incelemektedir. Bu yöntemler, malzeme taşıma maliyetlerini en aza indirmek ve mekânsal organizasyonu iyileştirmek için tasarlanmıştır. Çalışma, CRAFT'ın mevcut yerleşim planlarının değiştirilmesi için daha uygun olduğunu, CORELAP'ın ise yeni tesis tasarımları için ideal olduğunu ortaya koymaktadır. Uygulama sonuçları, CORELAP'in malzeme taşıma maliyetlerini %7 azaltarak 845'ten 787'ye düşürdüğünü, CRAFT'ın ise %12'lik bir azalma sağlayarak maliyetleri 747'ye indirdiğini göstermektedir. Bu iyileştirmeler operasyonel verimliliği ve uzun vadeli maliyet tasarruflarını artırmaktadır. Her iki algoritma da komple bir yeniden yapılandırma yerine kademeli yerleşim iyileştirmelerine odaklanarak büyük üretim kesintilerini önlemektedir. Simülasyon sonuçları, CRAFT'ın minimum yerleşim planı değişiklikleriyle verimliliği artırdığını, malzeme taşıma mesafelerini azalttığını ve üretimi hızlandırdığını doğrulamaktadır. Özellikle küçük ve orta ölçekli işletmeler için uygun maliyetli ve pratik uygulaması göz önüne alındığında, CRAFT bu çalışma için tercih edilen yaklaşım olarak kabul edilmiştir.

Optimization of Facility Layout and Production Planning Decisions in Flange Manufacturing Plants: Application of CRAFT and CORELAP Algorithms

Research Article

ABSTRACT

Efficient facility layout planning is essential for optimizing workflow, reducing material handling costs, and enhancing production efficiency. In flange manufacturing, ineffective layouts lead to increased transportation costs and production inefficiencies. Applying systematic layout optimization strategies is crucial for maintaining competitiveness and cost-effectiveness. This study examines the optimization of facility layouts using CRAFT (Computerized Relative Allocation of Facilities Technique) and CORELAP (Computerized Relationship Layout Planning) algorithms. These methods are designed to minimize material handling costs and improve spatial organization. The study finds that CRAFT is more suitable for modifying existing layouts, while CORELAP is ideal for new facility designs. Implementation results show that CORELAP reduced material handling costs by 7%, from 845 to 787, while CRAFT achieved a 12% reduction, lowering costs to 747. These improvements

enhance operational efficiency and long-term cost savings. Instead of a complete restructuring, both algorithms focus on incremental layout enhancements, preventing major production disruptions. Simulation results confirm that CRAFT increases efficiency with minimal layout modifications, reducing material handling distances and accelerating production. Given its cost-effective and practical application, particularly for small and medium-sized enterprises, CRAFT was deemed the preferred approach for this study.

1. Introduction

Facility layout planning is a fundamental aspect of manufacturing systems, playing a crucial role in enhancing operational efficiency, minimizing material handling costs, and optimizing production workflows. An effective facility layout strategically positions machinery, equipment, materials, and labor to streamline production processes, reduce unnecessary movements, and improve overall productivity. In industries such as flange manufacturing, where precision and efficiency are critical, optimizing facility layout is essential for maintaining competitiveness and meeting production demands (Pérez-Gosende et al., 2021).

As modern manufacturing environments become increasingly complex, dynamic facility layout planning (DFLP) has gained significant attention. Unlike static layouts, DFLP adapts to real-time changes by incorporating machine learning and heuristic optimization methods (Salimpour et al., 2025). These adaptive models allow facilities to dynamically reconfigure workstations, reducing downtime and enhancing flexibility in response to fluctuating production requirements. Among the widely used automated optimization techniques, CRAFT (Computerized Relative Allocation of Facilities Technique) and CORELAP (Computerized Relationship Layout Planning) have emerged as efficient tools for facility layout design. These methods facilitate a data-driven approach to optimization, reducing manual intervention while improving precision and cost-effectiveness in layout planning. Their application ensures reduced material handling distances, improved process synchronization, and increased overall efficiency in flange manufacturing plants.

This study provides a comparative analysis of the CRAFT and CORELAP algorithms in the context of flange manufacturing, a domain where facility layout optimization plays a crucial role in production efficiency. While both algorithms have been widely used in various industries, their direct comparison in this specific manufacturing sector has been limited. The research quantifies their efficiency improvements, demonstrating that CRAFT is more effective for modifying existing facility layouts, achieving a 12% reduction in material handling costs, while CORELAP is better suited for designing new layouts, reducing transportation costs by 7%. By implementing and validating these algorithms in a real-world production environment, this study bridges the gap between theoretical optimization models and practical applications, offering a structured decision-making framework for facility planners and manufacturing engineers.

Furthermore, the study advances the understanding of cost-effective facility layout strategies, providing empirical evidence on material handling cost reductions and their impact on workflow efficiency. Unlike previous research that primarily focuses on theoretical or simulation-based results, this study integrates real-world manufacturing constraints to enhance the practical applicability of these optimization techniques. Additionally, it highlights the importance of integrating AI-driven methods for future research, suggesting that machine learning-based dynamic facility layouts could further optimize production efficiency. By addressing these research gaps, the study contributes valuable insights for small and medium-sized enterprises (SMEs), helping them optimize facility layouts without significant disruptions to production.

This study is not only limited to the application of CRAFT and CORELAP algorithms in flange production, but also makes a methodological contribution to the literature by systematically comparing the performance differences between these two methods in the light of real data. While most studies focus on applying a single algorithm in a specific context, this research provides a practical roadmap for algorithm selection by comparatively investigating both methods on the same production system. Moreover, the validation of the obtained results by simulation demonstrates the validity of the proposed layouts in the real production environment and increases the scientific depth of the study. Thus, the study adds value to the literature not only in terms of application domain diversity but also in terms of methodological clarity, analytical validation and contribution to decision support processes.

This paper's remaining sections are arranged as follows: A comprehensive review of the literature on algorithmic approaches and facility layout optimization is given in Section 2. The research methodology, including the data gathering procedure and the implementation of the CRAFT and CORELAP algorithms, is covered in Section 3. The implementation outcomes and a comparison of the two approaches are provided in Section 4. The results are discussed in detail in Section 5, with particular attention paid to how they may affect production practices and literature. Section 6 brings the study to a close and presents suggestions for future lines of research in facility layout optimization.

2. Literature Review

Facility layout planning has long relied on heuristic algorithms that iteratively construct or improve layouts using inter-department relationship data. Systematic Layout Planning (SLP), for example, is a classic qualitative method using relationship charts to arrange departments by desired proximity, providing an initial layout based on qualitative workflow relationships before quantitative optimization. CRAFT is a widely adopted improvement algorithm that starts with an initial layout and swaps department locations to reduce material handling cost. Studies have shown that computer-aided layout algorithms like CRAFT often outperform manual planning methods (Lewis and Block, 1980). For instance, applying CRAFT has significantly reduced transport distances and costs in real factories. Prasad et al. (2014) reported a tailored plant layout via CRAFT that minimized inter-department travel and improved flow efficiency. Moreover, using CRAFT in combination with a construction algorithm

can yield superior results: Mulugeta et al. (2013) demonstrated that generating a new layout with CORELAP (a construction method) and then refining it with CRAFT achieved better performance than using CRAFT alone. CORELAP, on the other hand, is a constructive heuristic that builds a layout from scratch by placing departments sequentially according to highest adjacency priority. By using closeness ratings (e.g. flow intensities) to decide placement order, CORELAP produces layouts where highly interacting departments are adjacent. Galbraith and Miller (1990) showed early on that CORELAP can generate efficient adjacency-based designs, and this has been validated by many practical applications over time. Together, these traditional heuristics (like SLP for initial qualitative design, CORELAP for constructive layout generation, and CRAFT for iterative improvement) formed the foundation of computer-aided layout planning.

In recent years, data-driven and AI-based approaches have augmented these classical methods. Simulation combined with reinforcement learning (RL) has been explored to automatically discover high-performance layouts. For example, Choi et al. (2024) integrated discrete-event factory simulation with an RL algorithm to iteratively improve a production floor layout. Their approach achieved a 3.8% reduction in total logistics travel distance and an 11% decrease in the number of AGVs required. This shows that an intelligent agent can learn to optimize facility layouts beyond what human heuristics might attain. Similarly, Zhao and Duan (2024) applied a deep reinforcement learning model to a workshop layout problem, treating layout decisions as a real-time combinatorial optimization. The DRL-based system dynamically adjusted the workshop configuration and significantly improved throughput and decision speed compared to a static layout. These AI-driven techniques illustrate how modern algorithms can autonomously refine layouts in complex, changing environments – discovering layout improvements that may not be obvious to human planners. They effectively supplement classic methods like CRAFT and CORELAP by learning from simulation feedback and large state spaces.

Beyond heuristics and RL, numerous metaheuristic optimization techniques have been applied to the facility layout problem, given its combinatorial complexity. Metaheuristics such as genetic algorithms (GA), simulated annealing (SA), particle swarm optimization (PSO), and ant colony optimization (ACO) are popular for exploring vast layout design spaces. Genetic algorithms encode layout configurations as "chromosomes" and use evolutionary operators (selection, crossover, mutation) to evolve better layouts over successive generations. This helps escape local optima by combining high-quality features from different layouts. Simulated annealing is a probabilistic technique inspired by metal annealing; it occasionally allows non-improving layout moves (with decreasing probability) to avoid getting trapped in poor local layouts. This method can methodically improve an initial layout and has the advantage of simplicity. A recent multi-objective variant by Nordin et al. (2023) incorporated a force-directed graph model to adjust department positions, simultaneously optimizing multiple criteria (e.g. distance and congestion) in the layout. Particle swarm optimization treats each candidate layout as a "particle" moving through the solution space, adjusting its position based on its own experience and the best positions found by the swarm. PSO has been effectively applied to continuous layout

optimization problems; for example, Salimpour et al. (2024) used PSO to optimize a dynamic layout and demonstrated substantial reductions in handling effort. They report that such swarm-based searches can balance exploration and exploitation to find near-optimal workstation arrangements in complex facilities. Ant colony optimization, inspired by ant foraging, has also been used for facility layouts. Multiple artificial "ants" construct layout solutions by probabilistically favoring decisions (department placement sequences, flow connections) that have high pheromone levels (i.e. were part of successful past layouts). Over many iterations, good layout decisions accumulate virtual pheromone, while poor ones dissipate, guiding the colony towards efficient arrangements. This approach, as noted by Tompkins et al. (2010), can yield layouts with low material handling costs by reinforcing desirable adjacencies. Overall, these metaheuristics provide robust search capabilities for layout design. They are especially useful for large-scale or highly non-linear problems where simple greedy heuristics might struggle – often finding more globally optimal layouts at the expense of additional computation.

Increasingly, researchers have also pursued hybrid and multi-objective strategies to address the multifaceted nature of facility layout design (balancing material handling cost, space utilization, safety, flexibility, etc.). By combining algorithms or integrating multi-criteria decision-making (MCDM) tools, such hybrid approaches aim to produce layouts that satisfy multiple goals simultaneously. For example, Prayogo et al. (2020) demonstrated in a construction site layout problem that a hybrid metaheuristic (using two algorithms in sequence) outperformed any single algorithm, resulting in a more efficient arrangement of site facilities. One notable strategy is a two-stage heuristic: Jiang et al. (2023) proposed a logistics-oriented two-phase approach where a metaheuristic first generates layout alternatives optimized for material handling cost, and then a second stage uses domain-specific rules to fine-tune the layout for transport efficiency. This two-step method produced layouts that were both cost-effective and logistically practical, improving upon layouts obtained from a single pass of optimization. Another approach is to treat layout design as inherently multi-objective. Nordin et al. (2023) introduced a multi-objective model that integrates simulated annealing with graph-based adjustments to department positions. By simultaneously optimizing multiple performance metrics (e.g. travel distance and congestion), their method achieved a better overall balance in the layout than single-objective optimizations, using a force-directed "graph drawing" correction to reduce bottlenecks. In another study, İnce and Taşdemir (2024) combined MCDM techniques with a layout algorithm. They used AHP and PROMETHEE to evaluate and select an optimal factory location (identifying the best industrial zone for a new plant), then applied CORELAP to design the internal layout for that site. This integrated approach ensured both the macro-level decision (site selection) and micro-level layout were optimized – in their case yielding a smoother production flow and lower handling costs for a furniture manufacturing facility. Data-driven hybrids have also emerged: Saisud and Kongkaew (2025) developed a framework that augments CORELAP with association rule mining (to derive frequent flow relationships from actual production data) and a fuzzy AHP for weighting layout criteria. In a para-rubber plywood factory, their hybrid model reduced material handling distance by nearly 40% and saved

around $6,200 in annual fuel costs. These examples show that combining the strengths of different methods – whether two algorithms in tandem, or analytical decision tools with layout heuristics – can address complex real-world requirements more effectively. Hybrid and multi-objective strategies often produce superior layouts compared to single-method approaches, especially when multiple criteria must be satisfied concurrently.

The effectiveness of these techniques is evidenced by numerous case studies across industries. In manufacturing settings, systematic layout planning and computerized methods have yielded dramatic improvements. For instance, in a packaging factory, Tjusila et al. (2021) applied SLP, CRAFT, and CORELAP to redesign the floor. The best layout (from SLP) reduced total travel distance by about 60.2% and cut material handling costs by 44.3%. This optimized design was later validated using simulation (Promodel/FlexSim) to confirm the smoother. In a warehouse operation, Febianti et al. (2020) examined the raw material warehouse of a cement manufacturer and identified inefficiencies in the original layout. By using CORELAP to generate a new layout and then applying CRAFT for fine-tuning, they significantly reduced the total transportation distance for materials. The new warehouse layout improved operational efficiency and decreased handling time, addressing the capacity and flow issues of the old arrangement. In job shop production, Laosiritaworn et al. (2020) used a simulation-based CORELAP approach to improve a sheet-metal job shop layout. Different layout scenarios were simulated, and the CORELAP-designed layout shortened production times and material travel distances, demonstrating the value of simulation-aided planning in a complex job-shop environment. Similarly, Mebrat and Haile (2023) optimized a machine shop layout (Fasil Engineering, Ethiopia) by combining CORELAP for initial placement with CRAFT for iterative refinement. The result was a 74.3% reduction in material handling cost and a 22.1% decrease in total travel distance for parts, a dramatic improvement underscoring how even small factories benefit from algorithmic layout design. Small manufacturers have also seen meaningful gains: Devi and Prabowo (2023) report a case of a home-based tools company (UD. Doa Emak) where a CORELAP layout followed by CRAFT adjustments increased efficiency by about 3.3% compared to the original floor plan. While modest, this improvement was accompanied by a tangible reduction in monthly material travel distance and handling cost, showing that even incremental efficiency gains are valuable for a small enterprise. Likewise, Ordu and Korhan (2022) applied a discrete-event simulation to the layout design of a textile firm's cutting department, reporting about a 14% increase in production efficiency. This finding underscores the value of integrating simulation with layout planning: by validating and quantifying improvements in a real setting, such approaches help ensure that theoretical optimizations translate to real-world gains. Sari et al. (2023) reported more significant savings in a general manufacturing facility, where both CORELAP and CRAFT methods were tested, and the CRAFT-optimized layout was ultimately selected. It reduced the monthly material movement distance to ~1,755.8 meters – a 51.98% improvement in flow efficiency – and saved approximately Rp. 778,146 per month in handling costs. This illustrates how proper layout optimization can directly cut recurring operational expenses. Beyond manufacturing, these methods

extend to service and tourism settings as well. Jati et al. (2020) planned the layout of a "tourism education village" in Yogyakarta with 24 different facilities (lodging, workshops, visitor centers, etc.). Using the CORELAP algorithm, they arranged the village facilities based on closeness relationships, placing related functions near each other. The result was a more logical, efficient village layout that improved visitor flow and service delivery – highlighting that classical layout algorithms can be applied creatively outside of factories (in parks, campuses, and other public facility networks). Across all these cases, the common outcome is clear: a systematic, quantitative approach to layout design produces measurable improvements. By reducing unnecessary travel distances, minimizing material handling, and streamlining flows, companies achieved shorter process times and lower costs. These real-world successes validate the theoretical benefits of methods like CRAFT and CORELAP, often showing significant percentage gains over the prior layouts.

Although CRAFT and CORELAP algorithms have been applied in various sectors, a systematic and comparative evaluation of these methods on the same data set is rarely found in the literature. Moreover, while in many studies the proposed layouts are presented only based on theoretical cost calculations, the results of this study are tested by simulation, which strengthens the validity of the recommendations in real production conditions. In this respect, the study fills the gap in the literature, enabling comparative analysis of algorithms not only in different application areas but also in the same environment and increasing the adaptability of the results to the field. Thus, the strengths and weaknesses of the methods are revealed more clearly, and decision makers are provided with a more scientific framework for algorithm selection.

In summary, optimizing facility layout is a critical factor in operational success, and the literature consistently underscores its importance. A well-structured layout improves workflow synchronization, reduces wasted movement and handling, and maximizes use of space and resources. These efficiencies translate into shorter production cycles and lower operating costs, boosting overall productivity and competitiveness. Conversely, a poor layout can create bottlenecks, excessive transport, higher labor demands, and frustration on the shop floor – ultimately hindering performance and profitability. As manufacturing systems evolve and product variety increases, layouts must be both efficient and adaptable. The growing complexity of modern operations (advanced automation, just-in-time production, etc.) makes robust layout design strategies even more vital. Facility layout optimization should therefore be viewed not as a one-off task but as an ongoing improvement process. By leveraging traditional heuristics alongside advanced techniques (AI, simulation, metaheuristics, and hybrids), organizations can ensure their facility layouts remain efficient, responsive to change, and aligned with strategic goals. This comprehensive literature review shows that from classical algorithms to cutting-edge AI, the tools are available to continually refine facility layouts for better performance.

3. Material and Method

3.1. Material

This section outlines the materials and methods used to optimize the facility layout of a flange production plant using CRAFT and CORELAP algorithms. The study aims to improve material flow efficiency, reduce transportation costs, and enhance overall production performance by applying these optimization techniques.

The study was conducted at a flange production facility, located in the Bursa Organized Industrial Zone. The company specializes in the production of fasteners and machined parts for the automotive industry. The facility has a total production area of 1,200 m², with 900 m² of enclosed space, employing 43 personnel.

The production process includes multiple stages such as machining, drilling, welding, grinding, and quality control. These processes are essential for ensuring the final quality and dimensional accuracy of the produced flanges.

The research was carried out within the company's flange production process, which involves several sequential steps:

- Preparation of the work order by the production planning department,
- Procurement of raw materials required for the ordered flanges,
- Providing technical drawings of the materials to the manufacturing department and initiating pre-processing preparations,
- Transporting raw materials to CNC (Computer Numerical Control) lathe machines for preliminary machining to obtain semi-finished products,
- Further machining of semi-finished materials in CNC lathes to achieve the required dimensions,
- Transferring the machined materials to CNC vertical machining centers for hole drilling and countersinking operations to achieve the final product state,
- Performing quality control inspections, rectifying defective parts through welding if necessary, and reprocessing,
- Transferring completed products to the storage area for packaging,
- Loading packaged products onto transport vehicles for shipment.

A flange is a standardized structural component used to connect two pipes or attach a piping element (e.g., pump, valve, filter, check valve) to a system. In some applications, flanges are also employed to transmit rotational motion between mechanical components. Although primarily used in piping systems, flanges have increasingly been integrated into machine assemblies over time. This widespread adoption has extended their applications beyond pipelines to various industrial machinery. Additionally, flanges can be threaded and attached directly to mechanical components, further enhancing their versatility. While their predominant usage remains in piping systems, their functionality in machinery is also significant. The flange production flowchart is illustrated in Figure 1.
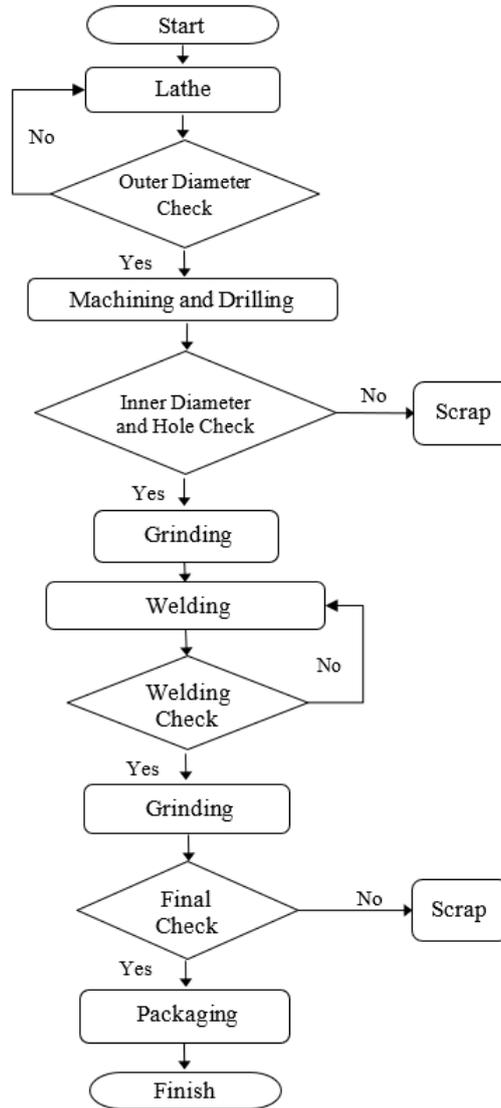
Figure 1. Flange production flowchart

When determining the dimensions of a flange, several critical factors must be considered to ensure compatibility and reliability within a piping system. These key considerations are listed in Table 1:

Table 1. Key considerations for flange dimensions

Factor	Description
System Pressure	Determines the required strength and material selection.
System Temperature	Affects material expansion and contraction properties.
Flange Material	Impacts durability, corrosion resistance, and mechanical performance.
Pipeline Diameter	Ensures proper fit and structural integrity.

The primary dimensions of a flange, which influence its mechanical properties and connection reliability, are detailed in Table 2:

Table 2. Flange dimensional parameters

Parameter	Description
Inner Diameter (d)	The internal measurement of the flange that aligns with the pipeline opening.
Outer Diameter (D)	The external perimeter of the flange, determining its total size.
Bolt Circle Diameter (K)	The distance between the centers of the bolt holes, ensuring secure fastening.
Thickness (T)	The wall thickness of the flange, influencing its mechanical strength.
Number of Bolts	The count of bolts required to achieve a secure and leak-proof connection.

3.2. Method

3.2.1. CRAFT Algorithm

CRAFT is a widely adopted optimization method in facility layout planning. It enhances manufacturing efficiency by strategically placing machines and workstations to minimize material handling distances and transportation costs (Sarıkaya et al., 2024). Operating iteratively, the algorithm evaluates cost-reducing modifications and exchanges department locations to achieve an optimized layout.

The key steps involved in the CRAFT algorithm, which contribute to an optimized facility layout, are summarized in Table 3:

Table 3. Implementation steps of CRAFT algorithm

Step	Description
Initial Layout Identification	Mapping the current layout of machines and workstations.
Transportation Cost Calculation	Determining distance-based transportation costs for material flow between workstations.
Optimization Model Construction	Formulating a mathematical model using linear or integer programming for layout optimization.
Evaluation of Initial Layout	Analyzing workflow efficiency and transportation cost metrics to identify inefficiencies.
Layout Adjustment Proposals	Suggesting modifications by relocating machines and reconfiguring workstation layouts.
Iteration and Optimization	Repeating the process until further cost reductions and workflow improvements are no longer feasible.

3.2.2. CORELAP Algorithm

The CORELAP algorithm is designed to optimize facility layouts by prioritizing adjacency relationships between workstations based on material flow frequency. By strategically placing departments with high interaction proximity, CORELAP minimizes material handling costs and enhances workflow efficiency. The main steps in the CORELAP algorithm, guiding its optimization process, are outlined in Table 4:

Table 4. Implementation steps of CORELAP algorithm

Step	Description
Data Collection	Gathering information on workstations, material flow, and interactions.
Relationship Identification	Assigning prioritization to workstation adjacency based on material flow frequency.
Computer Model Generation	Integrating collected data into a simulation model to generate various layout configurations.
Simulation and Evaluation	Simulating different layouts and assessing their efficiency based on material handling and workflow metrics.
Optimal Layout Selection	Choosing the most efficient configuration based on simulation results and cost-effectiveness.
Implementation and Monitoring	Deploying the new layout and continuously monitoring performance to make necessary adjustments.

3.2.3. Comparison and Advantages of CRAFT and CORELAP

CRAFT is highly effective in refining existing facility layouts through iterative improvements, significantly reducing transportation costs and optimizing workflow efficiency. CORELAP is better suited for designing new layouts, ensuring efficient placement of workstations through adjacency-based optimization. Both algorithms contribute significantly to facility layout efficiency, with CRAFT excelling in incremental modifications and CORELAP being ideal for greenfield facility planning. This study integrates CRAFT and CORELAP algorithms to evaluate and optimize facility layout efficiency, adopting a data-driven approach to enhance production flow and reduce operational costs.

4. Implementation of CRAFT and CORELAP Algorithms

4.1. CRAFT Algorithm Implementation

The CRAFT algorithm was applied iteratively to improve the existing layout. The initial and optimized layouts were compared based on transportation costs and material handling efficiency.

The optimization model developed for this study aims to maximize profitability by optimizing the production sequence and product mix while minimizing costs associated with inventory, material handling, and layout modifications. The total cost consists of production costs, labor costs, holding costs, relocation costs, and transportation-related expenses. The primary constraints affecting this problem include demand fulfillment, inventory control, material movement, and spatial limitations. The strategic objective is to create an optimized plan that considers long-term decision-making for sustainable production improvements. The data collection phase focuses on essential facility layout parameters such as workstation types, distances between workstations, and transportation costs. These factors significantly impact the efficiency of material flow and overall production costs. The area requirements, machinery, personnel, and material specifications of each workstation are detailed in Table 5 to ensure an optimized layout design.

Table 5. Workstation area, machine, personnel, and material requirements

Process Name	Required Area (m²)	Machines/Tools	Number of Personnel	Material Requirement
Machining	300	CNC Lathe Machine	15	Sized Metal Block
Drilling	80	CNC Vertical Machining Center	3	Processed Metal Block
Welding	50	Gas Metal Arc Welding Machine	2	Flange Components, Welding Wire
Grinding	20	Belt Grinder	2	Flange Components, Abrasive Materials
Testing and Inspection	100	Assembly and Inspection Table	5	Flange

The distances between each workstation, which directly influence transportation costs, are provided in Table 6.

Table 6. Distances between workstations (meters)

Workstation	Machining	Drilling	Welding	Grinding	Testing and Inspection
Machining	0	10	15	20	25
Drilling	10	0	8	15	20
Welding	15	8	0	10	15
Grinding	20	15	10	0	8
Testing and Inspection	25	20	15	8	0

Additionally, material flow costs between workstations, a key factor in cost reduction efforts, are presented in Table 7.

Table 7. Material handling costs between workstations

Process	Machining	Drilling	Welding	Grinding	Testing and Inspection
Machining	0	4	2	3	5
Drilling	4	0	3	2	4
Welding	2	3	0	4	2
Grinding	3	2	4	0	1
Testing and Inspection	5	4	2	1	0

To achieve optimal efficiency, workstations are grouped based on material flow relationships. The workstation groups and their relative placement strategies are summarized in Table 8.

Table 8. Workstation grouping

Group	Workstations	Layout Strategy
Group 1	Machining, Drilling	Placed in close proximity
Group 2	Welding, Grinding	Placed in close proximity
Group 3	Testing and Inspection	Positioned in an optimal location

By arranging workstations in these clusters, transportation costs are minimized, and operational efficiency is enhanced. By placing Group 1 (Machining and Drilling) together, transportation costs between these operations are minimized. Similarly, Welding and Grinding workstations are located within close proximity to improve efficiency.

With the implementation of the optimized layout, the production line is expected to achieve a faster and more efficient flow, reducing material handling times and production costs. The flange production facility consists of a 600 m² enclosed manufacturing area. The existing facility layout is depicted in Figure 2.
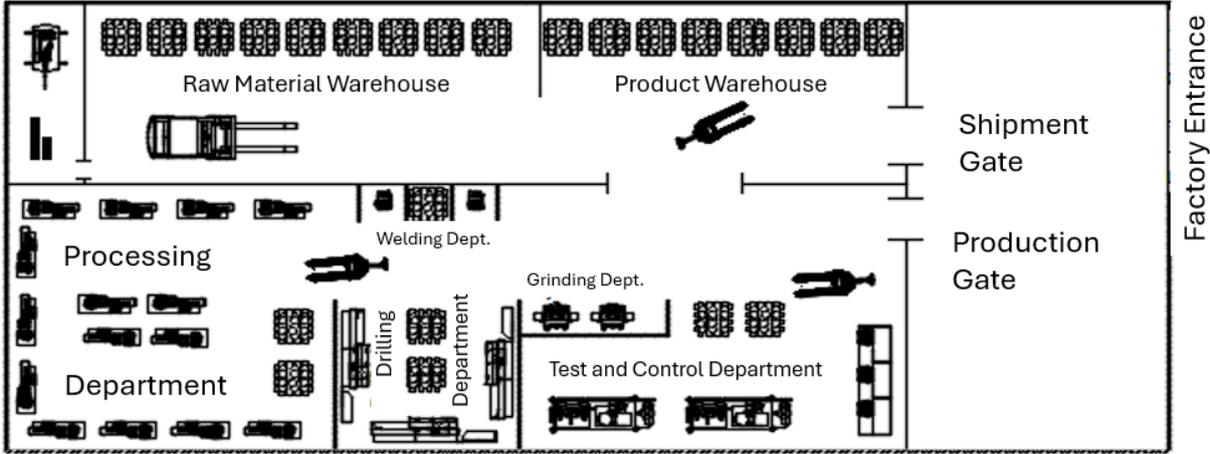

Figure 2. Current facility layout

The workflow transitions are visualized in Figure 3, which shows the process flow for the optimized layout.
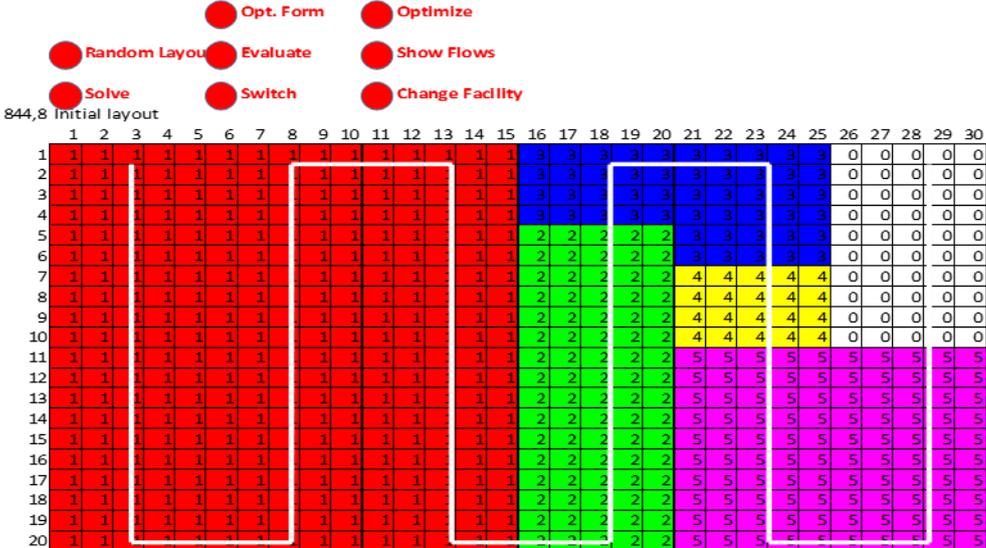

Figure 3. Process flow of the current layout of the plant in the CRAFT algorithm

Transportation cost of the current layout of the plant in the CRAFT algorithm is illustrated in Figure 4.

Facility Layout

Problem Name:	Production			Method:	Sequence		
Number Depts.:	5			Layout:	Aisle		
Length(cells):	20			Fill Departments:	No		
Width(cells):	30			Measure:	Rectilinear		
Area (cells):	600			Number Aisles:	6		
Cost:	845			Dept. Width:	5		

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
İşleme	1	300	300	7,5	10	1
Delik Açma	2	80	80	17,5	12	2
Kaynak	3	50	50	20,5	2,599999905	3
Taşlama	4	20	20	22,5	8	4
Test ve Kontrol	5	100	100	25	15	5

Figure 4. Transportation cost of the current layout of the plant in the CRAFT algorithm

After implementation, the layout and production flow should be continuously monitored and further improvements made over time. The actual implementation process of the CRAFT algorithm and monitoring afterwards ensures that the theoretical optimization is translated into practice. Through these processes, businesses can achieve and sustain cost-effective layouts. As illustrated in Figure 5, the optimized facility layout achieved through CRAFT implementation significantly improves workflow efficiency and reduces transportation costs.
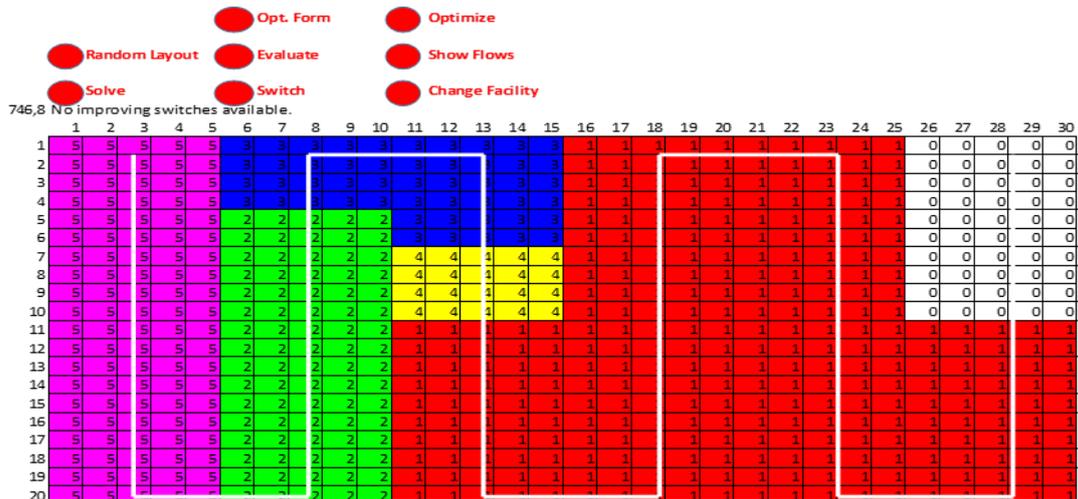

Figure 5. Process flow in optimized layout using CRAFT

While the transportation cost was 844.8 units in the current layout of the facility in the CRAFT algorithm, it is stated in Figure 6 that the transportation cost is calculated as 746.8 units with a decrease of approximately 12%. The impact of the algorithm can be maximized through regular monitoring and continuous improvement.

Figure 6. Optimal transportation cost of the facility according to CRAFT algorithm

The iterative optimization process ensures that facility layout decisions result in tangible operational benefits. As shown in Figure 7, the final refined facility layout demonstrates a streamlined production flow, reducing unnecessary material movement and enhancing overall throughput.

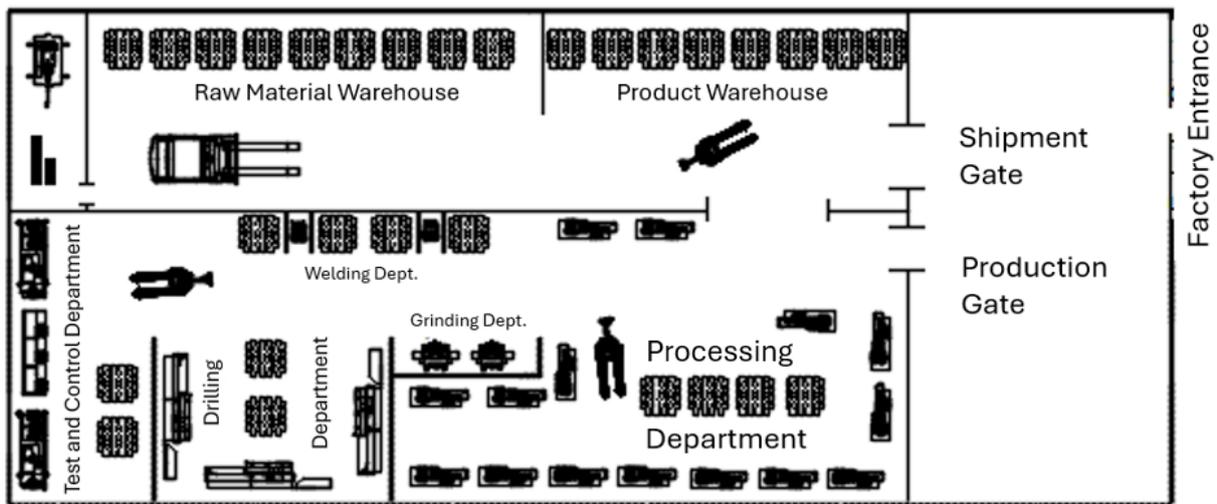**Figure 7.** Final optimized facility layout with CRAFT application

Following the implementation of the new layout, the calculated transportation cost before and after optimization is compared in Table 9.

Table 9. Transportation cost reduction using CRAFT

Layout Type	Transportation Cost (Units)
Current Layout	845
Optimized Layout (CRAFT)	747
Cost Reduction	12% decrease

By continuously monitoring and improving the layout through additional iterations, long-term efficiency and cost reductions can be sustained. This iterative process is essential for adapting to changing production demands and maintaining an optimized manufacturing environment.

4.2. CORELAP Algorithm Implementation

CORELAP was used to design a new facility layout. Workstations were arranged based on adjacency priorities, ensuring optimal material flow. To execute CORELAP, detailed data on workstation types, inter-station distances, and transportation costs were gathered, similar to the data utilized in the CRAFT application. Distance data plays a crucial role in calculating transportation expenses, as greater distances increase handling costs and material movement time. These costs serve as key factors in the CORELAP optimization model. The facility structure, including machine allocations, personnel distribution, and material requirements, remains consistent with the data presented in Table 5-8 of the CRAFT application.

In the CORELAP implementation phase, a qualitative evaluation is performed to assess the relative closeness between departments. The degree of closeness is scored based on the frequency and intensity of interactions between workstations. The closeness evaluation consists of six levels, as illustrated in Table 10.

Table 10. Closeness ratings

Value	Closeness rating
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness
U	Unimportant
X	Undesirable

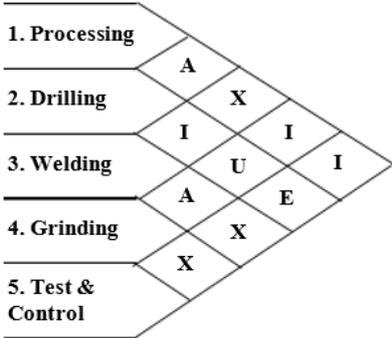Based on the closeness ratings, an activity relationship chart is created as shown in Figure 8.

Figure 8. Activity relationship chart

Each level assigns a specific letter-based importance rating to interdepartmental relationships. These letters correspond to a linear equivalent, allowing for a structured and quantifiable representation of workstation proximity as depicted in Table 11.

Table 11. Linear equivalent of significance levels

Relationship	Closeness rating	Diagram Lines
A	Absolutely necessary	≣≣≣≣
E	Especially important	≡≡≡
I	Important	══
O	Ordinary closeness	——
U	Unimportant	
X	Undesirable	∿∿∿∿

The activity relationship diagram visually represents these relationships, with strong and weak connections distinctly marked. The relationship diagram provides insights into optimal department placements without direct spatial constraints. Instead, it focuses on adjacency priorities based on workflow and material flow interactions. A graphical representation of workstation relationships is depicted in Figure 9.
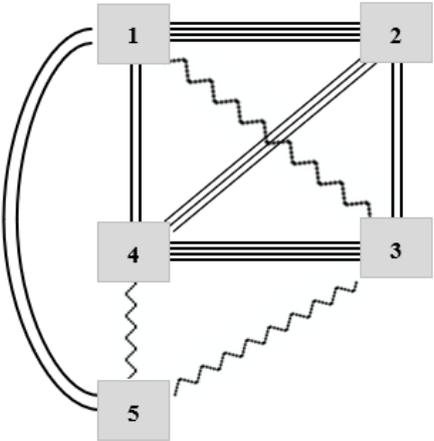

Figure 9. Relationship diagram

The importance of each relationship is categorized using predefined letter ratings, which are further quantified in Table 12.

Table 12. Closeness ratings in CORELAP algorithm

Symbol	Closeness ratings
A	10.000
E	1.000
I	100
O	10
U	0
X	-10.000

In the first iteration of the CORELAP algorithm, the closeness ratings values (CRV) obtained by placing the values in the matrix in Table 12, the area with the highest total importance is assigned to the first place in the layout and the area with the lowest total importance is assigned to the last place in the layout. After the first area is placed in the center, the other areas are placed in order around the center according to their relationships and flow data. At each step, the most suitable area is selected, and iterations are continued until the layout minimizes the total transportation distance and cost.

The iterative results of the CORELAP algorithm, including department placements and optimization scores, are detailed in Tables 13–16, which demonstrate how facility layout evolves with each iteration to achieve optimal efficiency.

Table 13. CORELAP algorithm 1st iteration

		Departments					Ratings						CRV	Order
		1	2	3	4	5	A	E	I	O	U	X		
Departments	1	-	A	X	I	I	1	0	2	0	0	1	200	
	2	A	-	I	U	E	1	1	1	0	1	0	11100	1
	3	X	I	-	A	X	1	0	1	0	0	2	-9900	
	4	I	U	A	-	X	1	0	1	0	1	1	100	
	5	I	E	X	X	-	0	1	1	0	0	2	-18900	5

Table 14. CORELAP algorithm 2nd iteration

		Departments					Ratings						CRV	Order
		1	2	3	4	5	A	E	I	O	U	X		
Departments	1	-	A	X	I	I	1	0	2	0	0	1	200	2
	2	A	-	I	U	E	1	1	1	0	1	0	11100	1
	3	X	I	-	A	X	1	0	1	0	0	2	-9900	
	4	I	U	A	-	X	1	0	1	0	1	1	100	
	5	I	E	X	X	-	0	1	1	0	0	2	-18900	5

Table 15. CORELAP algorithm 3rd iteration

		Departments					Ratings						CRV	Order
		1	2	3	4	5	A	E	I	O	U	X		
Departments	1	-	A	X	I	I	1	0	2	0	0	1	200	2
	2	A	-	I	U	E	1	1	1	0	1	0	11100	1
	3	X	I	-	A	X	1	0	1	0	0	2	-9900	
	4	I	U	A	-	X	1	0	1	0	1	1	100	3
	5	I	E	X	X	-	0	1	1	0	0	2	-18900	5

Table 16. CORELAP algorithm last iteration

		Departments					Ratings						CRV	Order
		1	2	3	4	5	A	E	I	O	U	X		
Departments	1	-	A	X	I	I	1	0	2	0	0	1	200	2
	2	A	-	I	U	E	1	1	1	0	1	0	11100	1
	3	X	I	-	A	X	1	0	1	0	0	2	-9900	4
	4	I	U	A	-	X	1	0	1	0	1	1	100	3
	5	I	E	X	X	-	0	1	1	0	0	2	-18900	5

Supporting the CORELAP algorithm with real-time monitoring makes it possible to continuously monitor changing conditions within the plant and take action based on this information. The information obtained from real-time monitoring data is used to support the decision-making process and make CORELAP layout arrangements dynamic.

The CORELAP algorithm becomes more dynamic and efficient with the integration of real-time monitoring and decision making. This allows for more flexible and proactive management of operations, especially in ever-changing production or logistics environments. In light of the available data about the facility under study, using the CORELAP algorithm and the iterations, the appropriate facility layout order specified in Table 17 was found, the cost was determined as 787 units as shown in Figure 10, and the process flow of the transportation cost in the CORELAP algorithm is shown in Figure 11.

Table 17. Facility layout with CORELAP algorithm
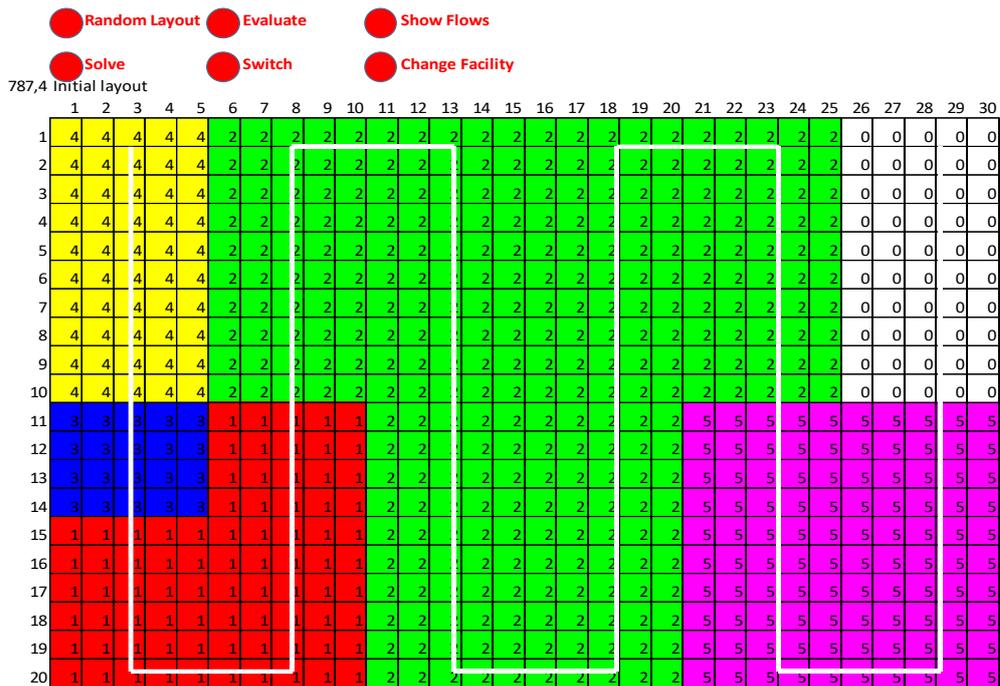
Order of Placement	1	2	3	4	5
Department	2	1	4	3	5

Figure 10. Transportation cost with CORELAP algorithm

Facility Layout

Problem Name:	Production		Method:	Traditional	
Number Depts.:	5		Layout:	Aisle	
Length(cells):	20		Fill Departments:	No	
Width(cells):	30		Measure:	Euclidean	
Area (cells):	600		Number Aisles:	6	
Cost:	787		Dept. Width:	5	

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
Delik Açma	1	80	80	5,625	15,75	3
İşleme	2	300	300	15	8,33333302	4
Taşlama	3	20	20	2,5	12	2
Kaynak	4	50	50	2,5	5	1
Test ve Kontrol	5	100	100	25	15	5

Figure 11. CORELAP algorithm process flow of transportation cost

In the plant layout proposed by the algorithm shown in Figure 11, the transportation cost decreased by approximately 7% and was determined as 787.4 units.

Additionally, Figure 12 illustrates the final optimized layout obtained through CORELAP.
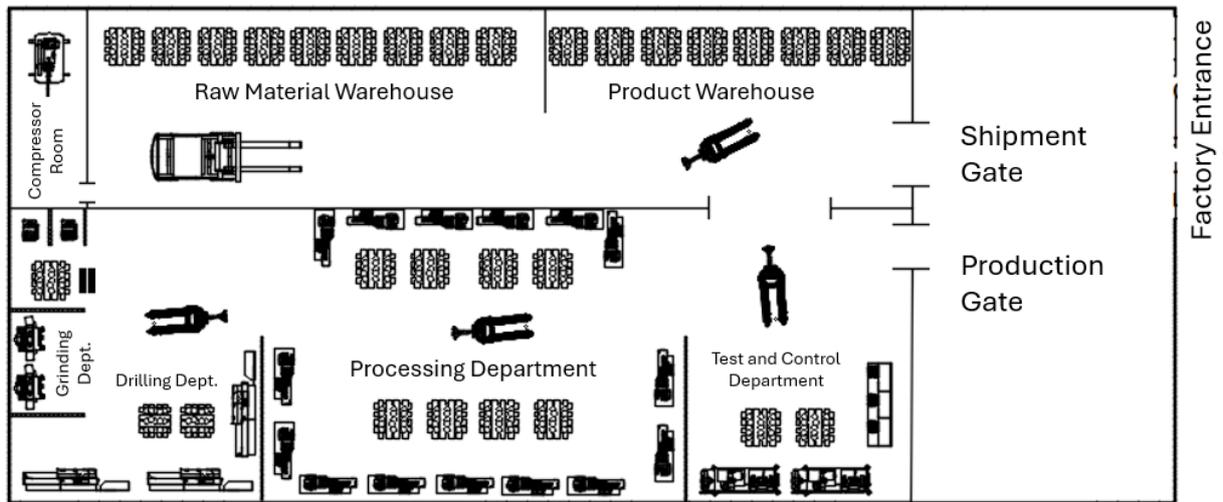
Figure 12. Optimized facility layout using CORELAP algorithm

The CORELAP algorithm generates the optimal layout of the departments by using the values of the CRV and relationship given in the table above. In this process, the main objectives are to reduce costs and improve workflow. The algorithm minimizes operational costs, especially by placing departments with dense relationships together. It has been stated that the CORELAP algorithm provides continuous improvement through iterative processes in layout optimization (Güneş and Aksoy, 2019).

CORELAP algorithm is an effective method used especially in facility layout problems. The continuous improvement process of this algorithm proceeds in iterative steps to optimize a specific objective and aims to achieve a better solution in each cycle. The continuous improvement cycles of layout algorithms such as CORELAP have been reported to have critical impacts on the cost benefits of facility layout (Tompkins et al., 2010).

Following the CORELAP-based redesign, a comparative analysis was performed to assess improvements in workflow efficiency and transportation cost reductions. Since the same facility data was used in both CORELAP and CRAFT applications, the initial transportation cost calculations remain consistent. Table 18 summarizes the transportation cost reductions achieved with CORELAP algorithm.

Table 18. Transportation cost reduction using CORELAP

Layout Type	Transportation Cost (Units)
Current Layout	865
Optimized Layout (CORELAP)	787
Cost Reduction	7% decrease

4.3. Comparative Analysis

The application of CORELAP resulted in a reduction in transportation costs from 845 units to 787 units, reflecting an approximate 7% cost savings. In comparison, the implementation of CRAFT reduced

transportation costs from 845 units to 747 units, yielding a 12% reduction. These results highlight the effectiveness of CRAFT in optimizing facility layouts with minimal modifications.

In flange manufacturing plants, leveraging CRAFT and CORELAP algorithms can significantly optimize facility layouts and enhance production planning. CRAFT is particularly effective for refining existing layouts, while CORELAP is more suitable for designing new facility layouts from scratch. A combined approach can maximize efficiency and cost savings, making it a valuable strategy for manufacturing optimization.

Table 19 provides a comparative analysis of the transportation cost reductions achieved with each algorithm.

Table 19. Comparison of CRAFT and CORELAP algorithms

Algorithm	Initial Cost (Units)	Optimized Cost (Units)	Reduction (%)
CRAFT	845	747	12%
CORELAP	845	787	7%

5. Discussion

The comparative analysis confirms the key insights regarding layout optimization. First, the improvements achieved (12% cost reduction for CRAFT vs. 7% for CORELAP) are consistent with other findings in the literature. This suggests that when modifying an existing facility, incremental improvement (CRAFT) can yield significant gains with minimal disruption. In contrast, creating a layout from scratch (CORELAP) provides a robust baseline design but may not match the cost savings of fine-tuning iterative improvement in a real facility. Our results are consistent with a simulation study by Ordu and Korhan (2022) in a textile factory, which reported a ~14% increase in productivity through layout redesign. While the sectors differ, the similar magnitude of the efficiency gain underscores the overall benefit of systematic layout revision across manufacturing sectors.

The study provides practical evidence that combining CRAFT and CORELAP can systematically reduce material handling costs; the clear difference in cost savings demonstrates how each algorithm's strength applies to different scenarios; additionally, by incorporating real production data and simulation, the research validates theoretical improvements under real constraints, thereby increasing scientific rigor.

These contributions go beyond flange production. They provide a general framework; facility designers can employ either method depending on whether the plant layout exists (CRAFT) or new (CORELAP). The findings also show that these accessible strategies can help SMEs achieve significant efficiency gains. For example, CRAFT's ease of adoption and low requirement for disturbance make it ideal for SMEs (who may lack the resources for a comprehensive redesign).

Finally, by emphasizing these findings, the study clarifies the new knowledge it provides to the literature. It does more than just apply proven algorithms to a specific scenario; it also compares their effectiveness, adds simulation-based validation, and presents a structured algorithm selection process.

6. Conclusion

The implementation of CRAFT and CORELAP algorithms has demonstrated significant improvements in facility layout optimization, particularly in reducing material handling costs and improving workflow efficiency. Given the critical role of material flow and workstation placement in flange production, these algorithms provide tailored solutions for existing facility layouts. Efficient facility layout planning directly impacts production speed, cost-effectiveness, and product quality in manufacturing industries such as flange production. The reduction of material handling distances, optimal workstation positioning, and streamlined processes contribute to both short-term cost savings and long-term competitive advantages.

By applying CRAFT and CORELAP, the facility's efficiency was enhanced, allowing for more effective resource utilization. These algorithms are well-supported both theoretically and practically, demonstrating their applicability in industrial environments. Both algorithms operate based on facility-specific data, including workflow patterns, transportation costs, and inter-workstation relationships. Instead of making radical layout changes, they focus on incremental improvements that lead to significant efficiency gains. This approach minimizes production interruptions while optimizing facility layouts in a cost-effective manner. Facility layouts can be categorized as either improvement algorithms (modifying an existing layout) or establishment algorithms (designing a layout from scratch). CRAFT is primarily used for refining existing layouts, whereas CORELAP is more suitable for initial facility design. Therefore, CRAFT was deemed the more appropriate choice for this study.

The application of CORELAP resulted in a reduction in transportation costs from 845 units to 787 units, reflecting an approximate 7% cost savings. In comparison, the implementation of CRAFT reduced transportation costs from 845 units to 747 units, yielding a 12% reduction. These results highlight the effectiveness of CRAFT in optimizing facility layouts with minimal modifications.

This study concludes that CRAFT is a more suitable methodology for SMEs due to its ease of implementation, adaptability as a facility improvement algorithm, and its superior cost-saving capabilities compared to CORELAP. By making incremental adjustments to the existing facility layout, transportation costs were minimized while maintaining production continuity. Simulation results further validated CRAFT's effectiveness, confirming its potential for improving facility layouts without requiring extensive modifications. CRAFT's advantages include its low implementation cost, ease of use, and ability to reduce material handling distances, which ultimately accelerates production processes. Through continuous monitoring and refinement, this approach provides a sustainable solution for facility layout optimization in manufacturing industries.

This study provides actionable insights for facility planners in flange manufacturing, demonstrating that iterative CRAFT optimizations can yield superior efficiency in existing layouts, while CORELAP is more beneficial for new layouts. Future research should explore hybrid AI-driven models to further refine layout optimization techniques.

Ethical Statement:

This study does not involve any human participants, animals, or sensitive data, and it adheres to ethical research standards in accordance with institutional and academic guidelines.

Acknowledgement

The author extends his sincere gratitude to Hayrullah ÇAVUŞOĞLU for his invaluable contributions to this research. His insights and expertise have greatly enhanced the development and implementation of the study.

Conflict of Interest

The author declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Summary of Researchers' Contribution Rate Declaration

The author declares that he has contributed 100% to the article.

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