Proceedings of the 11th North American International Conference on Industrial Engineering and Operations Management, Milwaukee, Wisconsin, USA, June 9-11, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/NA11.20260087
Published: June 9, 2026

Facility Layout Optimization for an Original Equipment Manufacturer: An Industry-Engaged Capstone Project

Maria A. Fariña
Student
Department of Engineering Technology
Northwestern State University of Louisiana
Natchitoches, LA 71497, USA
mfaria386188@nsula.edu

Md Shahriar J. Hossain
Department Head and Associate Professor
Department of Engineering Technology
Northwestern State University of Louisiana
Natchitoches, LA 71497, USA
hossains@nsula.edu

Abstract

This paper presents a year-long, industry-engaged senior design project conducted within the Industrial Engineering Technology program at Northwestern State University of Louisiana, focused on solving a real-world facility layout problem for a local original equipment manufacturer (OEM). The partner company operates under a make-to-order production environment and experienced significant inefficiencies due to an ad-hoc facility layout characterized by overlapping machine assignments, excessive material handling, and frequent cross-traffic. To address these challenges, a student team applied systematic facility layout planning supported by quantitative, data-driven analysis. The methodology involved mapping the existing shop-floor layout, developing from–to charts based on product routing frequencies, and calculating total material travel distances as the primary performance metric. Multiple alternative layout configurations were generated and evaluated using an objective function that minimized weighted travel distance while accounting for spatial, safety, and operational constraints. The selected layout realigned workstations to better follow dominant process flows and reduce backtracking. Results show that the proposed layout achieved an estimated 18.9% reduction in total material handling distance, decreasing travel from approximately 7,699 feet to 6,243 feet, while also reducing cross-traffic and congestion. Beyond operational improvements, the project demonstrates the educational value of a year-long, industry-collaborative capstone experience. Students gained hands-on exposure to facility planning, operations analysis, and professional problem-solving within real industrial constraints. The study highlights a scalable framework for integrating applied facility layout optimization into engineering technology curricula and illustrates how academic–industry partnerships can deliver tangible benefits to both students and manufacturing organizations.

Keywords
Facility Layout Optimization, Senior Design Project, Industry–Academic Collaboration, Material Handling Analysis.

1. Introduction
Modern manufacturing facilities operate under increasing pressure to improve efficiency, reduce operational costs, and remain competitive in highly customized production environments. Facility layout plays a critical role in achieving

these objectives, as poor spatial arrangements can lead to excessive material handling, longer lead times, safety risks, and underutilized resources. These challenges are particularly pronounced in small and medium-sized manufacturers operating under make-to-order (MTO) production systems, where high product variety and fluctuating demand require flexible yet efficient layouts. Despite their importance, facility layouts in such environments often evolve incrementally rather than strategically, resulting in inefficiencies that accumulate over time. Addressing these inefficiencies is essential not only for improving operational performance but also for sustaining long-term manufacturing viability.

This study was conducted as a year-long capstone design project within an Industrial Engineering Technology program, in collaboration with a small Original Equipment Manufacturer (OEM). The company produces a wide range of custom and standard industrial equipment, including specialized elevators, feed hoppers, and shelling machines, within a single production facility. Due to the diverse product mix, shared equipment, and flexible scheduling requirements, the facility layout is developed in an ad-hoc manner, without systematic alignment to dominant process flows. Multiple products are often assembled simultaneously, leading to overlapping machine assignments, frequent cross-traffic, and non-linear material movement across the shop floor. Although the facility nominally follows a cellular layout, limited space and frequent reconfiguration have resulted in backtracking, crisscrossing flows, and congestion, increasing material handling time and reducing throughput. Furthermore, the existing layout offers limited flexibility to accommodate changes in product mix, exacerbating inefficiencies as demand patterns shift.

The motivation for this research arises from the need to systematically redesign such organically evolved layouts using data-driven methods that are both practical and scalable for small manufacturing environments. The goal of the project was to redesign the plant layout to better align with actual product process flows, thereby reducing material handling effort, improving workflow continuity, and enhancing safety. By partnering directly with industry and embedding the work within a senior design framework, this study also addresses a broader educational need: providing students with authentic, real-world problem-solving experiences that bridge theory and practice. The hypothesis guiding the project was that reorganizing machines and workstations according to predominant flow patterns would significantly reduce unnecessary movement, shorten travel distances and cycle times, and minimize cross-traffic. The following sections present the background literature, methodology, results, and discussion of both operational and educational outcomes derived from this industry-engaged senior design experience.

1.1 Problem Statements

Based on the industrial context and observed inefficiencies, this study addresses the following problem statements:

a) The existing facility layout results in excessive material handling distances due to non-linear and overlapping product flows.
b) Shared machinery and workspace create cross-traffic and congestion, negatively impacting productivity and safety.
c) The ad-hoc evolution of the layout lacks systematic alignment with dominant process sequences in a make-to-order environment.
d) Limited layout flexibility restricts the facility's ability to adapt efficiently to changes in product mix and demand.
e) There is a need for a structured, data-driven layout redesign methodology that is feasible for small manufacturers and transferable through engineering technology education.

The Research Question for this project is: To what extent can a systematic, data-driven facility layout redesign reduce material handling distance and improve workflow efficiency in a make-to-order original equipment manufacturing facility?

1.2 Objectives

The objective of this study is to redesign the facility layout of a small Original Equipment Manufacturer (OEM) operating in a make-to-order environment to improve operational efficiency. Specifically, the study aims to: (1) evaluate the existing layout and quantify material handling inefficiencies using data-driven metrics; (2) identify dominant product process flows and misalignments in the current layout; (3) develop and assess alternative layout configurations that minimize total material handling distance; (4) propose a practical, implementable layout that improves workflow, safety, and flexibility; and (5) demonstrate the effectiveness of an industry-engaged, year-long senior design project as a framework for applied facility layout optimization.

2. Literature Review

Facility layout optimization is a well-studied area in industrial engineering, with a rich body of literature spanning classical methods to modern algorithmic approaches. Recent studies have explored various strategies to improve manufacturing layouts and efficiency. For instance, Pérez-Gosende *et al.* (2021) categorized facility layout problems as static or dynamic, and noted a transition in solution techniques from traditional heuristic methods to advanced metaheuristics and mathematical optimization tools. This extended review supports the use of algorithmic or matrix-based models in layout planning. Similarly, Wei *et al.* (2025) proposed an enhanced hybrid genetic algorithm to optimize equipment layouts in reconfigurable manufacturing systems, demonstrating superior accuracy and efficiency compared to traditional methods. In addition to methodological advances, case studies illustrate the practical impact of layout improvements. Zúñiga *et al.* (2021) developed a simulation-based optimization approach that accounts for both production and logistics constraints, offering a holistic and flexible framework for complex, customized manufacturing environments. In one case, optimizing an existing plant's layout led to significant improvements in material flow and reduced operational costs, validating the feasibility of such approaches in industry (Kovács & Kot, 2017). Likewise, Salins *et al.* (2024) applied lean manufacturing principles combined with Systematic Layout Planning (SLP) in a steel processing facility, achieving a 34% reduction in total material flow distance and a 26% improvement in space utilization after the redesign.

Further contributions in the recent literature emphasize multi-objective and intelligent optimization techniques for facility layouts. Park *et al.* (2025) compared several metaheuristic algorithms, including Simulated Annealing, Particle Swarm Optimization (PSO), and the NSGA-II genetic algorithm, for layout planning in a matrix manufacturing system. Their study showed that advanced metaheuristics can efficiently handle complex layout problems, resulting in layouts that improve productivity and responsiveness under Industry 4.0 demands. In another innovative approach, Sajadieh *et al.* (2024) integrated production simulation with reinforcement learning to optimize facility layout and intra-facility logistics simultaneously. By incorporating automated guided vehicle (AGV) routing into the layout optimization, their method yielded notable reductions in material travel distance and the number of transport vehicles required. Jiang *et al.* (2023) focused on a specialized scenario of logistics-driven layout design. They developed an algorithm tailored for facilities constrained by fixed transport lines (such as conveyor systems or overhead tracks), demonstrating that even in such constrained environments, significant efficiency gains can be realized through algorithmic layout optimization. These studies collectively inform our project by highlighting state-of-the-art techniques (genetic algorithms, simulation-based optimization, machine learning) as well as proven principles SLP and lean methodologies for improving facility layouts.

3. Methods

Our methodology began with a thorough *assessment of the current layout* and the flow of materials through the facility. The senior design team mapped out the physical arrangement of all major workstations and equipment in the plant. Key production operations were identified, and a **list of operations** was compiled in the typical process order for the various products. The primary stations (with abbreviations) included [Rigsby, *et. al.* 2025]: Raw Materials Receiving (R), CNC Plasma Cutting (PL), Band Saw (B), Press Brake/Rolling (PR), Drill Press (D), Sheet Metal Welding (SW), Cleaning (C), Assembly (A), Lathe/Threading (L), Structural/TIG Welding (TW), Painting (P), a Unique Machining station (U) for special tasks, and Storage/Shipping (ST). Using historical job data and input from the company, the team determined the *sequence of operations* for three most common product types. We then developed an **operation sequence matrix** (or "from-to chart") that documented the frequency of material movement between each pair of stations [Figure 1], along with the distance between those stations in the current layout [Figure 2]. Note that Figure 2 displays only the distances between stations where material flow occurs.

Flow Table Fij — to

	R	A	B	C	D	U	L	P	TW	PR	W	CNC	Exit
R							62					158	
A													75
B					145				13				
C		13	145							62			145
D									62	145			
U		62											
L				145								62	
P						62							
TW								62		13			
PR							145				220		
W				13	62					145			
CNC			13	207									
Exit													

Figure 1. Frequency of material movement between each pair of stations

Existing travel distrance

	R	A	B	C	D	U	L	P	TW	PR	W	CNC	Exit
R							80					220	
A													274
B					40								
C		73.6	120							232			126
D									46	105			
U		152.4											
L				396								132	
P						228							
TW								142.8		60			
PR							116				168		
W				290.8	160					56			
CNC			122.8	460									
Exit													

Figure 2. Distance (in ft) between stations in the current layout.

These matrices provided a quantitative baseline of material handling: for example, how often and how far parts had to travel from the CNC Plasma to Welding, from Welding to Assembly, and so on. The total material travel distance in the current process flow was calculated by summing all flows in the from-to chart, weighted by frequency, that provides the Objective Function,

$$\text{Minimize Total Travel Distance } D_T = \sum_i \sum_j F_{ij} D_{ij} \quad \ldots\ldots\ldots\ldots\ldots\text{(Eq. 1)}$$

Here F_{ij} represents total materials flow from station i to station j, and D_{ij} represents the distance from station i to station j.

Using the baseline data, we performed a structured analysis to identify inefficiencies and opportunities for improvement. The team noted areas of high traffic and long transport distances in the current layout, especially movements that deviated from the ideal sequential flow. With these insights, we generated several *alternative layout configurations*. We evaluated each candidate layout using the matrix of flows and distances, recalculating the total material handling distance for each alternative following Eq. (1). Key factors considered during evaluation included: the distance between sequential operations, the frequency of moves (higher-frequency connections were prioritized to be closer together), and any spatial or safety constraints (such as not blocking aisles or ensuring adequate space around machines). This quantitative evaluation was complemented by qualitative considerations, such as ease of supervision, logical workflow, and flexibility for future changes. In essence, the team applied an iterative process of *Systematic Layout Planning*, supported by the measured data, to narrow down to the most promising layout design.

Once an optimal configuration was selected, the proposed layout was developed into a detailed floor plan. The new layout was drawn to scale, showing the rearranged positions of all machines, workstations, and storage areas. Material flow lines were overlaid on the plan to visualize how a typical product would move through the production steps in the new arrangement. We then compared the proposed layout against the current layout on total travel distance (from the from-to analysis), for three representative products. We also checked that the proposed arrangement would fit within the existing building constraints and adhere to any regulatory or safety requirements (for example, maintaining clear emergency exits and forklift lanes). The outcome of this methodology was not only a recommended new layout, but also a **reproducible decision-making process** for facility layout design. The systematic approach we followed, from data collection and analysis to generating and evaluating alternatives, can be applied by the company for future layout revisions or by other practitioners facing similar problems. Throughout the project, students engaged with industry engineers for feedback, ensuring that the methodology and final design remained practical and aligned with real-world considerations.

4. Results and Discussion

The evaluation of the current facility layout revealed several inefficiencies. The material flow analysis showed that work-in-process often traveled in a zigzag path across the shop floor. For example, components cut at the CNC plasma (PL) had to be transported to a distant welding area and then back toward the center of the facility for assembly, causing unnecessary backtracking. The distance matrix and from-to chart for the existing layout quantified these issues: the cumulative material travel distance for a typical production cycle was **7,699 feet**. This figure accounts for all trips between stations weighted by their frequency. Such a long travel distance contributes to higher material handling time, increased labor for transport, and potential delays in production. Additionally, the team observed that certain aisles were used repeatedly for transporting different items, leading to congestion and interference between workflows. Figure 3 shows the current facility layout and illustrates the principal material flow routes. In this layout, raw materials enter at one corner of the building and finished products exit near the opposite corner, but the path between these points is convoluted. Key problem areas included the separation of the welding stations from the assembly area and the location of the cleaning/painting area, which required completed sub-assemblies to be moved twice across the floor.

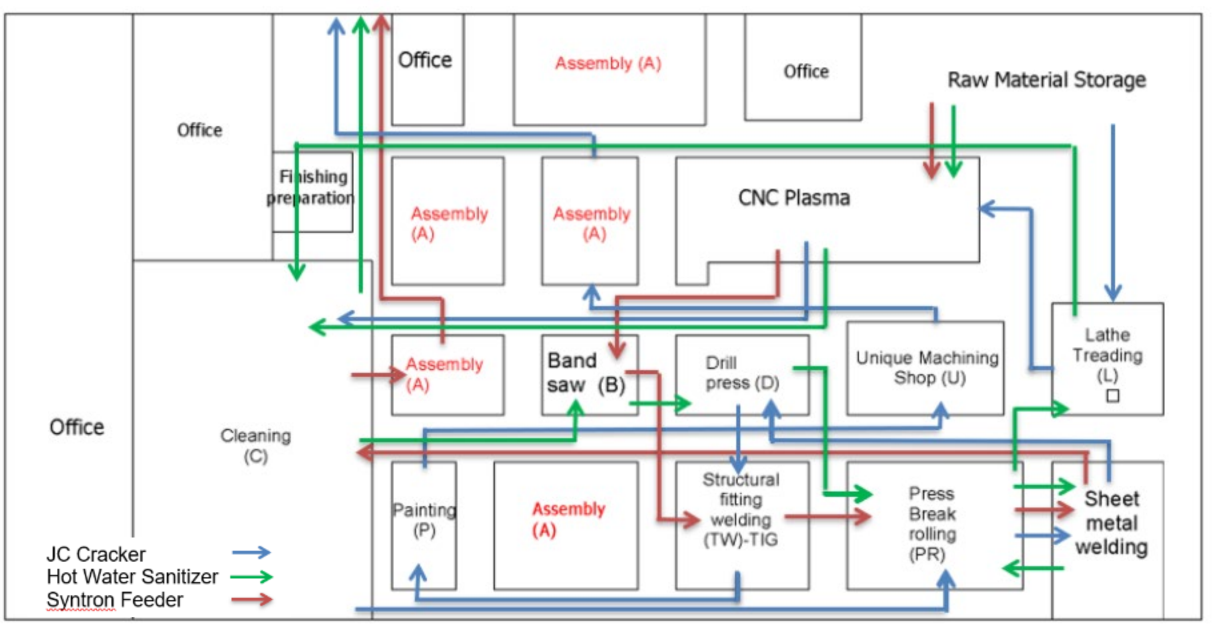

Figure 3. Current facility layout and material flow in the existing arrangement.

4.1 Proposed Improvements

The proposed layout significantly streamlined the production flow. In the improved design, machines and work areas were repositioned to follow the natural sequence of operations more closely. For instance, the welding stations (both sheet metal welding and TIG welding) were moved adjacent to the machining and assembly areas, since most products go from fabrication to welding and then directly into assembly. The cleaning and painting area was relocated nearer to the final assembly or storage area, so that finished parts do not need to travel back through the center of the shop. Figure 4 depicts the floor plan of the **proposed layout**, with arrows indicating the new material flow. As shown, the flow is much closer to a linear or U-shaped path, beginning at Raw Material Receiving and ending at the Storage/Shipping area without unnecessary detours. According to the updated from-to chart, the *total material travel* *distance* under the new layout is **6,243 feet**, which is about **18.9%** shorter than in the current layout. This reduction of approximately 1,456 feet in travel distance directly translates to lower material handling effort and time. In addition, the number of times material paths intersect (cross-traffic points) was reduced markedly, the new layout has clear, dedicated lanes for each product stream, reducing interference between different products being built simultaneously. These improvements are expected to reduce material handling costs (through less forklift use and manual carrying) and also improve production lead times. Another anticipated benefit is improved safety and ergonomics: with less cluttered travel paths and fewer crossing movements, there is a lower risk of accidents or damage to parts in transit.

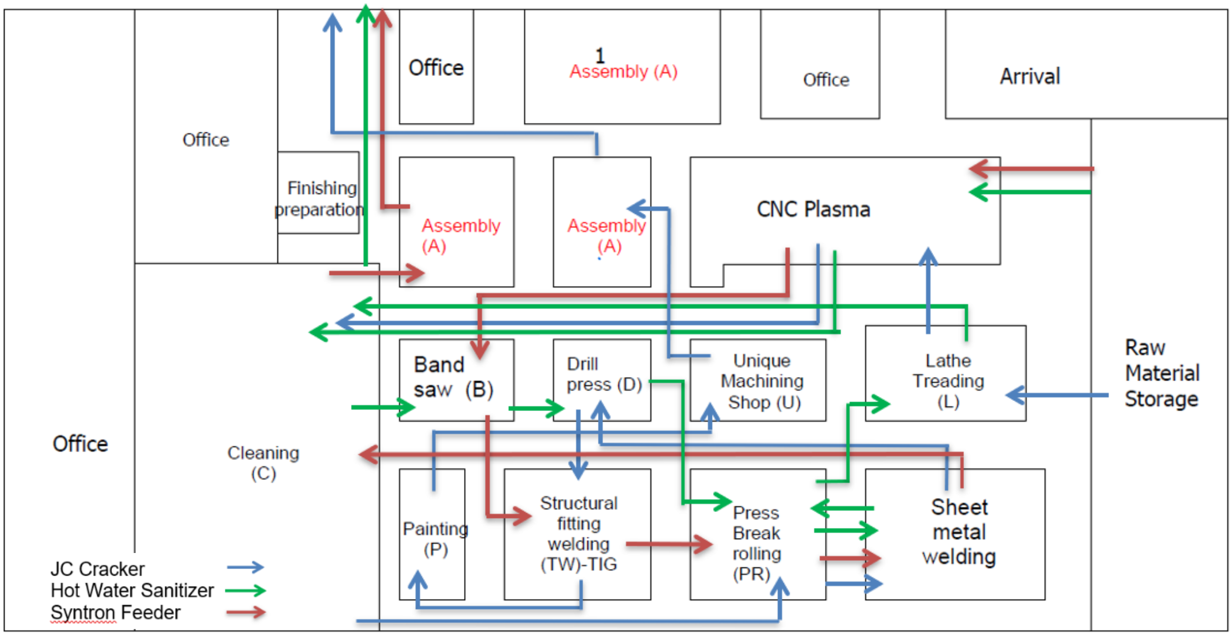

Figure 4. Proposed facility layout after optimization, showing a more streamlined material flow.

The distance between different stations in the proposed layout is listed in Figure 5. Note that Figure 5 displays only the distances between stations where material flow occurs.

New Travel Distance Dij													
	R	A	B	C	D	U	L	P	TW	PR	W	CNC	Exit
R							68.4					192.8	
A													224.8
B					40				86.8				
C		73.6	56							175.6			126
D									44.8	93.6			
U		119.2											
L				235.6								99.2	
P						154.8							
TW								44.4		60			
PR							108.4				168		
W				224.8	154.4					56			
CNC			136.8	460									
Exit													

Figure 5. Distance (in ft) between stations in the proposed layout.

Beyond the quantitative metrics, the project delivered visual and qualitative results that were well-received by the industry partner. The team prepared detailed layout diagrams (as partially shown in the figures above) and a comparison of key performance indicators for the current vs. proposed layouts. For example, if the original average production cycle took 10 days, the distance reduction and smoother flow in the new layout are expected to shave a certain amount of time off each cycle (pending further time-study analysis). While the exact throughput increase will depend on scheduling and operational factors, the company's managers acknowledged that the new layout would alleviate known bottlenecks, especially around the welding and assembly stages. The proposed floor plan also included some flexible storage and extra assembly space that can be used for staging or future equipment, which addresses the company's need for adaptability in a make-to-order environment. All results were documented with the intent that the company could implement the changes in phases, if an immediate full rearrangement is not feasible.

4.2 Discussion

The implementation of the proposed layout is poised to deliver several tangible benefits for the OEM. The roughly 19% reduction in material travel distance means that workers and forklifts will spend less time moving parts between processes. Over the course of many orders, this time savings can increase productive hours available for value-added work (actual fabrication and assembly) rather than transportation. In financial terms, reducing handling can lower labor costs and even energy costs if forklifts or other vehicles are used extensively. The smoother flow also reduces work-in-process inventory build-up, since items are less likely to wait in long transit queues or at congested areas. We anticipate that the new layout will result in a noticeable reduction in production lead time for the company's products, as components reach the assembly stage sooner and with less chance for delay. An important outcome is the elimination of several crossover points in the facility: previously, a cart of parts going from Welding to Assembly might cut through the path of raw material coming in, creating confusion or risk. In the new design, material pathways are more segregated, improving safety and making it easier for employees to follow standard operating procedures. The company can implement the layout changes gradually (e.g., over a weekend or holiday shutdown) to minimize disruption, and our plan includes recommendations for staging equipment moves and updating signage on the shop floor to reflect the new flow.

From an educational perspective, this senior design project provided invaluable *hands-on experience* for the students involved. The complexity of solving a real industry problem, with all the practical constraints of physical space, legacy processes, and human factors, taught the team how to apply theoretical knowledge to a practical scenario. Students had to use skills from across the Industrial Engineering Technology curriculum: data collection and analysis (for measuring distances and frequencies), operations research (to evaluate alternative layout quantitatively), facility design, and lean manufacturing principles (to identify waste in transportation). They also honed "soft skills" such as project management, as this was a year-long endeavor requiring scheduling, regular meetings with the company, and adjustments to scope when new challenges arose (for example, discovering mid-project that a planned machine relocation was not possible due to power supply locations). The collaboration with industry mentors meant that students received iterative feedback, mirroring an authentic engineering design cycle. By the end of the project, the students not only delivered a viable solution to the company but also gained confidence in tackling open-ended problems. This demonstrates the value of incorporating practical industry problems into the engineering technology curriculum, it prepares graduates to enter the workforce with a problem-solving mindset and an appreciation for continuous improvement. The company benefitted by obtaining a fresh perspective on their operations and a detailed plan that they can implement, while the students experienced the full cycle of defining a problem, researching solutions, implementing a design, and evaluating results.

5. Conclusion

This paper presented a successful example of a year-long senior design project in which students redesigned a manufacturing facility layout to solve a practical industry problem. The project was motivated by the needs of an OEM facing inefficiencies from a suboptimal layout. Through a systematic methodology, including mapping the current process, developing a sequence-of-operations matrix, and evaluating alternative configurations, the team arrived at a proposed layout that aligns closely with product flow. The results of the redesign are significant: an estimated 18.9% reduction in material handling distance, smoother and safer workflow with fewer cross-traffic conflicts, and a framework for the company to continually assess and improve its layout. These improvements have the potential to reduce production time and costs, thereby increasing the company's competitiveness in a make-to-order manufacturing environment.

Beyond the immediate industrial benefits, the project underscores the educational value of experiential learning in engineering technology programs. By engaging in a real-world problem, students connect classroom theory to hands-on practice, developing technical competencies in facility planning and honing teamwork and communication skills. The partnership between the university and the industry partner proved mutually beneficial and highlighted how academic projects can yield practical solutions for businesses. In future work, the company can build upon this project's foundation by investigating dynamic layout strategies or integrating automated material handling systems (e.g., AGVs) to further enhance efficiency. Similarly, the senior design program can use this project as a model for tackling other complex industry challenges, ensuring that students continue to gain relevant experience. In conclusion, the project demonstrates that thoughtfully executed senior design experiences can produce both immediate improvements for industry and lasting educational outcomes for students. The redesigned facility layout stands as a tangible achievement, and the methodologies and lessons learned are broadly applicable to facility layout optimization in various manufacturing settings.

References

Jiang, F., Li, L., Tang, Y., Zhang, H., and Liu, X., A facility layout algorithm for logistics scenarios driven by transport lines, *Applied Sciences*, vol. 13, no. 12, p. 7215, 2023. https://doi.org/10.3390/app13127215

Kovács, G., and Kot, S., Facility layout redesign for efficiency improvement and cost reduction, *Journal of Applied Mathematics and Computational Mechanics*, vol. 16, no. 1, pp. 63–74, 2017. https://doi.org/10.17512/jamcm.2017.1.06

Park, J., Lee, C., Oh, S. C., and Noh, S. D., Multi-objective optimization for layout planning of matrix manufacturing system, *International Journal of Precision Engineering and Manufacturing-Green Technology*, vol. 12, no. 3, pp. 1049–1067, 2025. https://doi.org/10.1007/s40684-025-00696-2

Pérez-Gosende, P., Mula, J., and Díaz-Madroñero, M., Facility layout planning: An extended literature review, *International Journal of Production Research*, vol. 59, no. 12, pp. 3777–3816, 2021. https://doi.org/10.1080/00207543.2021.1897176

Rigsby, K., Lockett, T., White, O., Williams, X., Hossain, S., and Caskey, C., Optimization of Facility Layout at a Custom Machine Builder to Minimize the Material Handling Time, *Unpublished Undergraduate Project*, Northwestern State University, Natchitoches, LA 71497, USA, 2025.

Ruiz Zúñiga, E., Flores García, E., Urenda Moris, M., Fathi, M., and Syberfeldt, A., Holistic simulation-based optimization methodology for facility layout design with consideration to production and logistics constraints, *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, vol. 235, no. 14, pp. 2350–2361, 2021. https://doi.org/10.1177/09544054211017310

Sajadieh, S. M. M., Ji, S., Kim, H., Yoon, H., Kwon, M., Han, J., Choi, H., Lee, D., and Noh, S. D., Optimization of the factory layout and production flow using production-simulation-based reinforcement learning, *Machines*, vol. 12, no. 6, p. 390, 2024. https://doi.org/10.3390/machines12060390

Salins, S. S., Zaidi, S. A. R., Deepak, D., Bindhu, A. S., and Manjunatha, B., Design of an improved layout for a steel processing facility using SLP and lean manufacturing techniques, *International Journal on Interactive Design and Manufacturing*, vol. 18, pp. 3827–3848, 2024. https://doi.org/10.1007/s12008-024-01828-9

Wei, X., Sun, J., and Jiao, H., New improved hybrid genetic algorithm for optimizing facility layout design of reconfigurable manufacturing system, *Scientific Reports*, vol. 15, Article 21416, 2025. https://doi.org/10.1038/s41598-025-97526-x

Biographies

Maria Fariña is an undergraduate student in the Industrial Engineering Technology program at Northwestern State University of Louisiana. She has research interests in industrial ergonomics, facility layout, manufacturing systems, and applied industrial engineering. Her academic work emphasizes data-driven analysis and industry-engaged problem solving. She is also a successful tennis player, a member of NSU's Women's Tennis team, and a member of the Institute of Industrial and Systems Engineers (IISE).

Dr. Md. Shahriar Hossain is the Department Head of Engineering Technology and an Associate Professor of Industrial Engineering Technology, with over 16 years of experience in academic research and teaching. His research interests include manufacturing systems and supply chain optimization, applied operations research, artificial intelligence for predictive modeling, renewable energy systems, and quality and lean production. His research contributions have received recognition from several national and international organizations, including IISE, AAER, and IEOM.