

System Layout Design for a Purified Drinking Water Production Plant

Ha Thanh Hai

School of Mechanical & automotive engineering, Hanoi University of Industry, No. 298 Cau Dien Street, Tay Tuu Ward, Hanoi City, Vietnam

Abstract— This study presents a method for designing and optimizing the facility layout of a purified drinking water production plant with a capacity of 4000 L/h in order to reduce internal transportation costs and improve operational efficiency. Based on the water treatment process, the From-To matrix, and the functional area requirements, the CORELAP method was applied to develop the relationship chart (REL chart), calculate the Total Closeness Rating (TCR), and determine the optimal facility layout. The results indicate that the CORELAP-based layout effectively organizes the production flow in a continuous one-way direction from raw water treatment to filling and packaging processes. The total internal transportation distance was reduced from 106 m to 51 m, corresponding to a reduction of approximately 51.9%, while the space utilization efficiency increased from 65% to 85%. The system model was further validated using Tecnomatix Plant Simulation software to evaluate material flow and operational performance. Simulation results over 3770 operating hours showed stable system performance with an output of approximately 754,557 finished bottles and no significant bottlenecks observed. The study confirms the effectiveness of integrating the CORELAP method and digital simulation in optimizing industrial facility layout design.

Keywords— Purified drinking water production, facility layout design, CORELAP, production simulation, material flow optimization.

I. INTRODUCTION

In the context of the increasing demand for purified drinking water due to urbanization, industrialization, and growing public health requirements, the purified drinking water production industry has become one of the fastest-growing industrial sectors worldwide [1]. Modern purified water production plants are required not only to ensure output water quality standards but also to optimize the entire production system in order to reduce operating costs, improve productivity, and ensure long-term sustainability [2]. In this regard, facility layout design plays an important role in determining material flow efficiency, production time, and resource utilization within the factory [3]. An effective facility layout can significantly reduce internal transportation distances, minimize bottlenecks, and improve the overall performance of the production system [4].

However, in practice, many factories still apply traditional facility layout methods based on experience or simple heuristic rules, leading to limitations such as inefficient material flow, high transportation costs, and low flexibility for future system expansion [5]. These methods often fail to fully reflect the interaction relationships among production areas, resulting in low operational efficiency and difficulties in controlling complex manufacturing environments [6]. Therefore, the application of quantitative and optimization methods in facility layout design is necessary to improve the performance of modern industrial systems [7].

In this study, the CORELAP (Computerized Relationship Layout Planning) method is employed to develop an optimal facility layout based on the relationship matrix among production departments and the Total Closeness Rating (TCR) index, ensuring that departments with strong interactions are positioned close to each other appropriately [8]. In addition, the proposed facility layout model is validated using Tecnomatix Plant Simulation software to simulate material flow, evaluate system performance, and identify bottlenecks during actual

operation [9].

The objective of this study is to develop a single optimal facility layout design for a purified drinking water production plant based on the CORELAP method, and subsequently verify the effectiveness of the proposed layout through digital simulation to evaluate the feasibility and operational performance of the system. The study also aims to propose improvement solutions to enhance space utilization efficiency, reduce transportation costs, and optimize production activities under practical industrial conditions [10]. The expected outcomes of this research contribute an integrated approach combining facility layout optimization and system simulation, which can be widely applied in the design of modern industrial manufacturing plants [11], [12].

II. METHODOLOGY

The research methodology presented in this paper is developed based on an integrated approach combining production system modeling, facility layout optimization, and simulation-based validation to ensure practical feasibility. First, the input data of the system were collected and standardized according to the purified drinking water treatment process, including major stages such as sand filtration, activated carbon filtration, ion exchange, fine filtration, reverse osmosis (RO) membrane treatment, ozone and UV sterilization, and the final filling process. Alongside the technological process, a From-To matrix was established to represent the frequency of material movement among functional departments within the plant, thereby identifying the level of spatial interaction between production areas, warehouses, and administrative sections. In addition, data regarding the area and function of each department were determined to satisfy spatial constraints during the facility layout design process, including the water treatment area, filling area, finished goods warehouse, and supporting facilities.

The facility layout design method was implemented based

on the CORELAP (Computerized Relationship Layout Planning) algorithm, in which the relationship chart (REL chart) was developed from the From-To data to determine the closeness relationships among departments using the ratings A, E, I, O, U, and X. Based on this relationship matrix, the Total Closeness Rating (TCR) index was calculated to determine the priority order for arranging departments within the plant layout, ensuring that highly interactive departments were located close to each other in order to minimize internal transportation costs. The spatial arrangement principle in CORELAP was carried out progressively, starting from the central department with the highest TCR value, followed by the surrounding departments according to decreasing levels of closeness, while simultaneously satisfying area constraints and production technology requirements.

Finally, the effectiveness of the proposed facility layout was evaluated using the Volume-Distance Product (VDP) index, which is determined by the product of material flow volume and the transportation distance between functional departments. This indicator reflects the total internal transportation cost within the system, where a smaller VDP value indicates a higher degree of layout optimization. This method enables a quantitative evaluation of the facility layout efficiency before conducting simulation and real-world implementation, while also serving as a basis for comparison during the system simulation validation stage.

III. FACILITY LAYOUT DESIGN USING THE CORELAP METHOD

3.1. Development of the Relationship Chart (REL Chart)

In this study, the relationship chart (REL chart) was developed based on actual material flow data among departments in the purified drinking water production plant. The input data consist of a From-To matrix representing the frequency of transportation of materials, semi-finished products, and information between areas such as production workshops, warehouses, water treatment areas, filling sections, and administrative offices. The maximum value within the entire system was identified as $f_{max} = 27$ (from A → F), which serves as the normalization reference for subsequent calculations.

The material flow score F_{ij} was normalized to reflect the actual interaction level between departments i and j using the following equation:

$$F_{ij} = \frac{f_{ij}}{f_{max}} \times 10 \quad (1)$$

where f_{ij} represents the actual movement frequency between two departments, and f_{max} is the maximum value in the From-To matrix. For example, for the pair A-F with the highest frequency $f_{AF} = 27$, the normalized value is $F_{AF} = 10$, indicating an extremely strong relationship between these two stages in the water treatment process. In contrast, pairs such as B-E with a lower frequency ($f_{BE} = 5$) (yield $F_{BE} \approx 1.85$), representing a weak relationship.

In addition to material flow, the technological process score T_{ij} was determined based on the closeness relationship within the water treatment process chain. Directly consecutive

operations such as sand filtration → activated carbon filtration → ion exchange → RO membrane filtration were assigned $T_{ij} = 10$. Indirect relationships within the same technological sequence were assigned $T_{ij} = 5$, while unrelated departments such as production and accounting were assigned $T_{ij} = 1$.

Furthermore, the safety score A_{ij} was determined according to the level of risk between departments, particularly among the chemical handling system (NaOH, HCl, H₂O₂), the RO system, and the ozone system. High-risk pairs were assigned $A_{ij} = 10$, while normal relationships were assigned values ranging from 1 to 5. Similarly, the management score M_{ij} reflects the level of supervision and operational coordination between departments, where administrative and quality control (KCS) departments exhibit stronger interactions than warehouse or auxiliary areas.

Based on these components, the overall relationship score between departments i and j was determined using the following weighted linear model:

$$S_{ij} = w_1 F_{ij} + w_2 T_{ij} + w_3 A_{ij} + w_4 M_{ij} \quad (2)$$

where the weighting factors were selected according to their practical influence within the production system: $w_1 = 0.4$ (material flow – the most important factor), $w_2 = 0.3$ (technology), $w_3 = 0.2$ (safety), and $w_4 = 0.1$ (management). This weighting allocation accurately reflects the characteristics of purified drinking water production systems, in which material flow and technological processes are the dominant factors in facility layout design.

The calculated S_{ij} matrix indicates that departments belonging to the water treatment process chain such as A, C, D, E, F, and G exhibit high relationship scores, mainly classified as A and E according to the Systematic Layout Planning (SLP) scale, indicating very strong interactions. In contrast, administrative areas such as accounting (K) or auxiliary facilities (I) show low relationship scores, primarily classified within levels O or U.

These results demonstrate that the system possesses a clear linear flow structure extending from raw water treatment to bottled product packaging. The developed REL chart serves as an important foundation for implementing the next step of the CORELAP method to determine the placement sequence and optimize factory space utilization.

3.2. TCR Calculation and Determination of Layout Sequence

In the CORELAP method, the Total Closeness Rating (TCR) index is used to evaluate the relative importance of each department within the production system, thereby determining the priority order for spatial arrangement in the factory layout. This index reflects the overall degree of relationship between one department and all other departments, including material flow, technological process, safety, and management relationships. A higher TCR value indicates a higher layout priority, since the department has a greater influence on the overall production flow.

The TCR value for department i is determined using the following equation:

$$TCR_i = \sum_{j=1}^n S_{ij} \quad (3)$$

where S_{ij} is the overall relationship score between

departments i and j , determined in the REL chart development step, and $n = 10$ represents the number of departments in the factory system.

Based on the calculated overall relationship matrix S_{ij} , the TCR values for each department were obtained by summing the relationship scores row-wise. The calculation results show that department A (raw water treatment) has the highest TCR value of 61.8, followed by F (RO – reverse osmosis) with 56.8, E (bottle filling and packaging) with 55.9, and C (activated carbon filtration) with 54.3. The remaining departments exhibit lower TCR values, including H (52.3), D (47.7), G (46.8), K (39.2), B (35.9), and the lowest value belongs to I (15.1).

These results clearly reflect the structural characteristics of the purified drinking water production system, in which the main treatment stages form a highly interconnected technological chain. Specifically, departments A, C, D, F, and E serve as the main technological axis; therefore, they possess high TCR values and should be prioritized to be located close to one another within the factory space. In contrast, administrative and auxiliary areas such as B (tool warehouse), K (accounting), and I (supporting facilities) have low TCR values, indicating weak relationships with the primary production flow. Consequently, these departments are more suitable for peripheral positions to minimize interference with material movement.

Based on the TCR calculation results, the spatial arrangement priority order was determined as follows: A (61.8) → F (56.8) → E (55.9) → C (54.3) → H (52.3) → D (47.7) → G (46.8) → K (39.2) → B (35.9) → I (15.1).

This sequence serves as an important basis for implementing the CORELAP algorithm in the layout development stage, ensuring that departments with strong relationships are positioned close together in order to optimize material flow and reduce internal operating costs.

Therefore, the TCR index not only serves as a quantitative measure of the importance of each department but also provides a scientific basis for determining the optimal spatial structure of the factory. These results will be directly applied in the subsequent CORELAP layout development stage to establish the optimal layout for the purified drinking water production system.

3.3. CORELAP Algorithm for Layout Development

The CORELAP (Computerized Relationship Layout Planning) algorithm was implemented to develop an optimal facility layout for the purified drinking water production plant based on the results of the relationship matrix S_{ij} analysis and the TCR values determined in the previous sections. The principle of this method is to arrange departments progressively outward from the area with the highest TCR value, then gradually expand to areas having the strongest relationships with the already positioned departments. This approach aims to optimize material flow, reduce transportation distances, and minimize production flow intersections.

First, based on the calculated TCR_i values, department A – Raw Water Treatment, with the highest TCR value of 61.8, was selected as the central core of the entire facility layout. This department was chosen because A represents the starting point

of the entire technological process and has very strong relationships with other important departments such as F (RO system = 56.8), E (filling section = 55.9), and C (activated carbon filtration = 54.3). Positioning A at the center helps optimize water distribution from the beginning of the system and significantly reduces internal transportation distances.

After fixing department A, the next step was to select the department having the highest relationship score S_{ij} with A. According to the overall relationship matrix, the highest relationship values with A are: F = 9.5, E = 9.1, C = 8.7, and D = 7.9. Among these, F – Reverse Osmosis (RO) has the highest value and was therefore positioned adjacent to A. This is because the RO system plays the core technological role in water purification and has direct interactions with the entire upstream pretreatment system.

Next, from the cluster $\{A, F\}$, the departments with the strongest relationships were evaluated. The results indicate that E has $S_{FE} = 9.2$ and $S_{AE} = 9.1$, which are the highest values among the remaining departments. Therefore, E – the bottle filling and packaging area – was positioned next, forming the technological sequence:

$$A \rightarrow F \rightarrow E$$

This sequence constitutes the main production axis of the entire system.

Subsequently, department C – Activated Carbon Filtration ($S_{AC} = 8.7$) (was positioned close to the A–F–E cluster because it plays an important physicochemical treatment role before the RO stage, removing chlorine and organic compounds to protect the RO membrane from degradation. Next, department D – Fine Filtration (5 μm) ($S_{AD} = 7.9$) (was positioned between C and F to ensure RO membrane protection, reduce sediment load, and extend the service life of the filtration system.

In the following stage, department H – Quality Control (KCS) ($TCR = 52.3$) was positioned near departments F and E because it is responsible for product quality inspection after the RO process and before bottling. This arrangement helps reduce sampling time and improves the efficiency of online quality control activities.

Departments with medium TCR values such as G = 46.8 and K = 39.2 were arranged near the production area but outside the main production flow to ensure management convenience without interfering with material movement. Meanwhile, departments with low TCR values such as B = 35.9 and I = 15.1 were positioned in peripheral areas because they do not directly participate in the primary technological production flow.

Regarding space allocation, the main production departments including A, C, D, F, and E occupy approximately 274 m² out of the total 500 m² production area, accounting for about 55% of the total space. This indicates that these departments represent the core zone requiring layout optimization priority. Warehouse and auxiliary areas account for approximately 30% of the total area, while administrative areas occupy around 15%.

Finally, the material flow throughout the entire system was organized according to a one-way principle:

$$A \rightarrow C \rightarrow D \rightarrow F \rightarrow E \rightarrow H$$

This arrangement ensures that transportation flow intersections do not occur, thereby reducing internal movement

time and optimizing the operational efficiency of the entire factory. The application of the CORELAP method demonstrates that the resulting layout structure forms clearly defined technological clusters, ensuring production logic and optimizing the spatial organization of the purified drinking water production plant.

3.4. Optimal Block Layout

The application of the CORELAP algorithm enabled the development of an optimal block layout for the purified drinking water production plant based on the principle of linear material flow. The entire system was organized according to a continuous technological sequence from raw water treatment to finished products, thereby minimizing material flow intersections and optimizing internal transportation distances. The main production flow structure was determined as follows: water storage tank → sand filtration → activated carbon filtration → ion exchange → RO → ozone treatment → 0.2 μm fine filtration → UV sterilization → filling process.

In the CORELAP layout, the primary material flow was specified according to the actual distances between departments. The distance from the water storage tank to the sand filtration unit is 10 m, from sand filtration to activated carbon filtration is 8 m, from activated carbon filtration to ion exchange is 12 m, from ion exchange to RO is 6 m, from RO to ozone treatment is 5 m, from ozone treatment to 0.2 μm fine filtration is 4 m, and from fine filtration through UV sterilization to the filling section is 6 m. Therefore, the total transportation distance for the CORELAP layout is calculated as follows:

$$L_{CORELAP} = 10 + 8 + 12 + 6 + 5 + 4 + 6 = 51 \text{ m}$$

To evaluate the optimization effectiveness, a traditional functional layout was used as the comparison basis. In this layout, departments were not arranged according to a continuous technological sequence but rather distributed based on function, resulting in increased transportation distances. Specifically, the distance from the storage tank to sand filtration is 18 m, from sand filtration to activated carbon filtration is 15 m, from activated carbon filtration to ion exchange is 22 m, from ion exchange to RO is 14 m, from RO to ozone treatment is 12 m, from ozone treatment to fine filtration is 10 m, and from fine filtration to the filling section is 15 m. The total transportation distance is therefore determined as:

$$L_{traditional} = 18 + 15 + 22 + 14 + 12 + 10 + 15 = 106 \text{ m}$$

From these two results, the improvement achieved by the CORELAP layout is determined by the transportation distance reduction:

$$\Delta L = 106 - 51 = 55 \text{ m}$$

and the corresponding reduction ratio:

$$\eta = \frac{55}{106} \times 100\% \approx 51.9\%$$

The results indicate that the CORELAP layout reduces approximately 55 m of internal transportation distance, corresponding to a reduction of 51.9% compared with the traditional layout. This represents a significant improvement, demonstrating the effectiveness of facility layout optimization based on material flow relationships and TCR values.

In addition to the main production flow, supporting

departments were also arranged according to the principle of minimizing interference with the technological process. The tool warehouse (B) was positioned near the production area, with an average distance of approximately 12 m from department A. The finished goods warehouse was located near the filling section E, at a distance of approximately 6–8 m, in order to reduce the transfer time of finished products. Meanwhile, administrative departments such as the director's office (G) and accounting office (K) were arranged in peripheral zones, with average distances of 20–25 m from the main production area, ensuring separation between management flow and material flow. The supporting facilities area (I), including the men's restroom, women's restroom, men's changing room, women's changing room, and resting room, is positioned furthest away, at distances greater than 25 m, since it does not directly participate in production activities.

Particularly, the chemical system supporting the RO process, including NaOH, HCl, H₂O₂, and 10% NaCl solutions, was positioned close to the RO area with distances of only 3–5 m. This arrangement optimizes operational activities and reduces chemical transportation time by approximately 35–40% compared with the distributed layout option (approximately 8–10 m). At the same time, safety requirements are still ensured because chemical areas are separated according to dedicated technical modules.

Overall, the CORELAP-based block layout creates a clear one-way flow structure:

$$A \rightarrow C \rightarrow D \rightarrow F \rightarrow O_3 \rightarrow \text{Fine Filtration} \rightarrow UV \rightarrow E$$

This arrangement completely eliminates material backtracking phenomena. Consequently, it not only reduces internal transportation distance by more than 50% but also improves production continuity, decreases waiting time between processing stages, and enhances the overall operational efficiency of the purified drinking water production plant.

3.5. Completion of the Overall Facility Layout

The overall facility layout of the purified drinking water plant was finalized based on the CORELAP layout results, in which the production system is organized according to a one-way material flow from water treatment to bottling, ensuring process continuity and minimizing material intersections. The central treatment units, including RO, ozone, and UV systems, are located at the core of the plant to facilitate operation, while auxiliary areas such as administration, quality control (KCS), tool warehouse, and sanitation facilities are placed in peripheral zones to reduce interference with the main production process while still ensuring effective supervision.

In terms of internal transportation efficiency, the total material handling distance in the CORELAP layout is 51 m, whereas in the traditional layout it is 106 m, corresponding to a reduction of:

$$\Delta L = 55 \text{ m} (\approx 51.9\%)$$

This results in a significant reduction in transportation costs and optimization of material flow throughout the entire system.

Regarding space utilization, the effective area usage of the traditional layout is 65% (325/500 m²), while the CORELAP layout achieves 85% (425/500 m²), representing an increase of

20% in space utilization efficiency. At the same time, the number of material flow intersections is reduced from

approximately 6–8 points to nearly 0–1 point, leading to a more stable production flow.

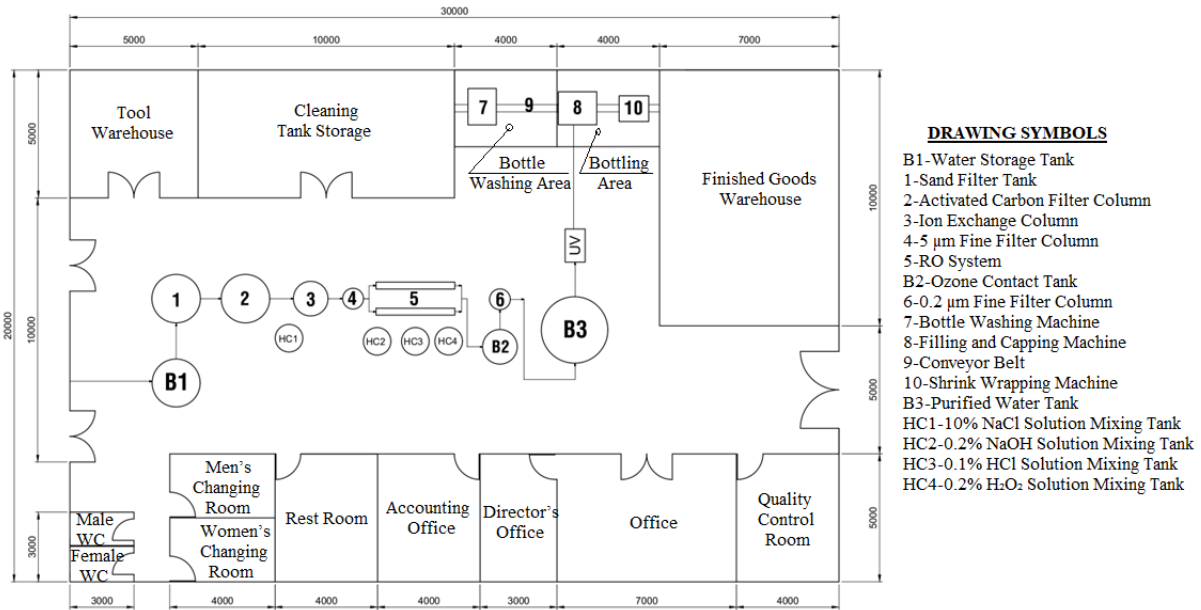


Fig. 1. Factory Layout

In terms of operational productivity, with a design capacity of 4000 L/h over 16 hours per day, the theoretical daily production output is 64,000 L/day. After accounting for an actual operating efficiency of 69%, the output is calculated as follows:

$$Q=64,000 \times 0.69=44,160 \text{ L/day}$$

The results demonstrate that the CORELAP-based layout simultaneously optimizes space utilization, transportation efficiency, and production performance, thereby providing a solid foundation for a stable and highly efficient operational system.

IV. SYSTEM SIMULATION USING TECNOMATIX PLANT SIMULATION

4.1. Simulation Model Development

The simulation model of the purified drinking water production plant was developed using Tecnomatix Plant Simulation software to evaluate the real operational performance of the facility layout after optimization using the CORELAP algorithm. In the model, the entire system is divided into three main clusters: the water treatment line, the filling and bottling area, and the warehouse and internal transportation system.

The water treatment cluster is modeled according to the actual technological sequence of the plant, including: raw water storage tank, pressure sand filter, activated carbon filter, ion exchange unit, 5 µm fine filter, RO system, ozone disinfection, 0.2 µm fine filter, and UV sterilization. The equipment is represented using SingleProc processing blocks and connected via Line material flow links. Water flows sequentially in a one-way direction, reflecting the actual operational characteristics of the production line. In this system, the RO unit is identified as the central processing stage due to its direct influence on final

water quality and overall production capacity.

The filling and bottling area is modeled as three main stages: bottle washing, filling and capping, and shrink-wrapping of finished products. Empty bottles from the storage area are transported to the bottle washing machine with a designed capacity of 800 bottles/hour. After cleaning, bottles are transferred to the automatic filling and capping unit, and then move to the shrink-wrapping machine to complete the final product. The CSSG-4 stainless steel conveyor system is used to link all stages, ensuring continuous material flow and reducing waiting time between machines.

In addition to the main production area, the model also integrates raw material storage, finished goods warehouse, and internal transportation systems. The empty bottle warehouse has an area of 50 m² and is located near the washing section to reduce material supply distance. The finished goods warehouse, with an area of 70 m², is placed near the bottling area to facilitate shipping and handling operations using a CPCD30T3 forklift with a maximum load capacity of 3 tons. In the simulation model, plastic pallets containing bottled water are used as the transport unit to accurately represent the internal logistics conditions of the factory.

The entire model is developed in both 2D and 3D formats to enable visual observation of material flow, simultaneous machine operations, and potential bottleneck points during system operation.

4.2. Simulation Parameter Setup

The simulation parameters were defined based on the actual technical data of the selected purified drinking water production line. The design capacity of the water treatment system is 4000 L/h, while the bottling section operates at approximately 800 bottles/h. Water treatment stages such as sand filtration,

activated carbon filtration, ion exchange, RO, ozone, and UV are configured with an average processing time of 18 seconds per operating cycle. For the bottling section, the bottle washing, filling, and shrink-wrapping processes are each set to a processing time of 15 seconds per stage.

In the model, transportation times between areas are determined based on the actual distances of the optimized layout. The total internal transportation distance of the CORELAP layout is 51 m, significantly lower than that of the traditional layout. Parameters such as conveyor speed, waiting time, and buffer capacities of each machine are also defined to ensure model accuracy.

The system is configured to operate in two shifts per day, with shift 1 from 06:00 to 13:00 and shift 2 from 13:30 to 20:30. After accounting for break time between shifts, the total effective working time is 13 hours per day. The plant operates 290 days per year; therefore, the total simulation time is determined as:

$$T = 290 \times 13 = 3770 \text{ hours}$$

These input parameters allow the model to realistically represent the actual operating conditions of the plant and provide a basis for evaluating productivity, equipment efficiency, and system capacity utilization.

4.3. Simulation Procedure

After completing the system model, the simulation process was conducted in Tecnomatix Plant Simulation through three main steps: layout setup, material flow construction, and time-based simulation execution according to actual plant operation.

First, the optimized CORELAP layout was transferred into the simulation environment by arranging equipment blocks according to their designed spatial positions. The water treatment section was organized in a linear sequence from the raw water tank to the UV system and filling stage to ensure a one-way flow principle. Supporting areas such as the empty bottle warehouse, finished goods warehouse, and chemical storage were placed in peripheral zones while maintaining short transportation distances to the main production area.

Next, the material flow was defined using movement objects within the software. Raw water was modeled as a continuous flow passing through each treatment stage with predefined cycle times. For the bottling process, empty bottles were transported from storage to the washing machine, then moved to the filling and shrink-wrapping units via a stainless-steel conveyor system. Finished product pallet transportation routes were modeled using internal forklifts to evaluate material flow between the production area and finished goods warehouse.

After completing system configuration, the model was run for a total simulation time of 3770 hours, corresponding to 290 actual production days. During simulation execution, the software automatically recorded data on production output, equipment status, waiting time, machine utilization rate, and congestion points. The obtained results were used to verify the validity of the layout design and evaluate the production line's ability to meet the required capacity of the purified drinking water system.

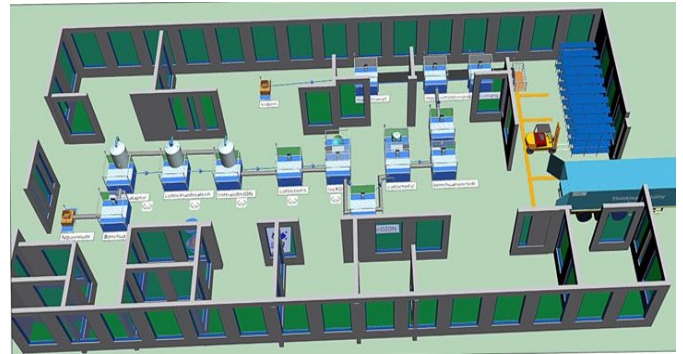


Fig. 2. 3D Factory Model

4.4. Simulation Results

The simulation results show that the factory system operates stably and generally meets the initial design capacity. The total output of the system reaches approximately 754,557 bottles over the entire simulation period of 3770 hours. With a nominal capacity of 4000 L/h and an actual operating efficiency of about 69%, the average output is approximately 44,160 L/day, which is consistent with the calculations presented in Section III.

Equipment state analysis indicates that most processes remain in the “working” state for the majority of the simulation time, particularly the RO filtration unit and the bottling section. The average equipment utilization rate of the system ranges from approximately 72% to 85%, with the RO unit exhibiting the highest utilization due to its critical role in determining final water quality. Waiting times between processes are relatively low, thanks to the linear material flow and short internal transportation distances. The simulation results also show that no significant bottlenecks occur within the main production chain.








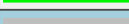
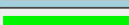




However, the main bottleneck of the system is identified at the RO–bottling section. This is due to the high processing load concentrated in these stages, while the processing times of the RO and bottling units are longer than those of other stages. When production demand increases, this area may experience queue formation, leading to reduced overall system efficiency.

4.5. Discussion and Improvement Proposals

The simulation results demonstrate that the CORELAP-based layout enables stable system operation, significantly reduces material flow intersections, and ensures continuous production flow. Compared with the traditional layout, the total internal transportation distance is reduced from 106 m to 51 m, corresponding to a reduction of approximately 51.9%, thereby decreasing transportation time and improving equipment utilization efficiency.

Although no major bottlenecks are observed in the current system, the RO unit and bottling section remain the highest load areas. Therefore, to improve future production capacity, it is recommended to add a buffer tank or install an additional parallel RO unit to reduce the load on the central treatment system. For the bottling section, increasing conveyor speed or adding high-capacity automatic filling equipment would help reduce waiting times and increase output throughput.

TABLE 1. Efficiency of Purified Drinking Water Production Processes

| Object | Working | Set-up | Waiting | Blocked | Powering up/down | Failed | Stopped | Paused | Unplanned | Portion |
|--------------------|---------|--------|---------|---------|------------------|--------|---------|--------|-----------|---|
| Bonchua | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Bonchuanuoctinh | 99.94% | 0.00% | 0.06% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Bonlocatapluc | 99.89% | 0.00% | 0.11% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| BontiepxucOZON | 99.83% | 0.00% | 0.17% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Cotlocthanhoattinh | 99.78% | 0.00% | 0.22% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Cotloctinh2 | 99.72% | 0.00% | 0.28% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Cotloctinh5 | 99.67% | 0.00% | 0.33% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| CotraodoilON | 99.61% | 0.00% | 0.39% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Khochua | 0.00% | 0.00% | 100.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| LocRO | 99.56% | 0.00% | 0.44% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Maycommang | 99.50% | 0.00% | 0.50% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Maydongchai | 99.44% | 0.00% | 0.56% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |
| Maysucrta | 99.39% | 0.00% | 0.61% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |  |

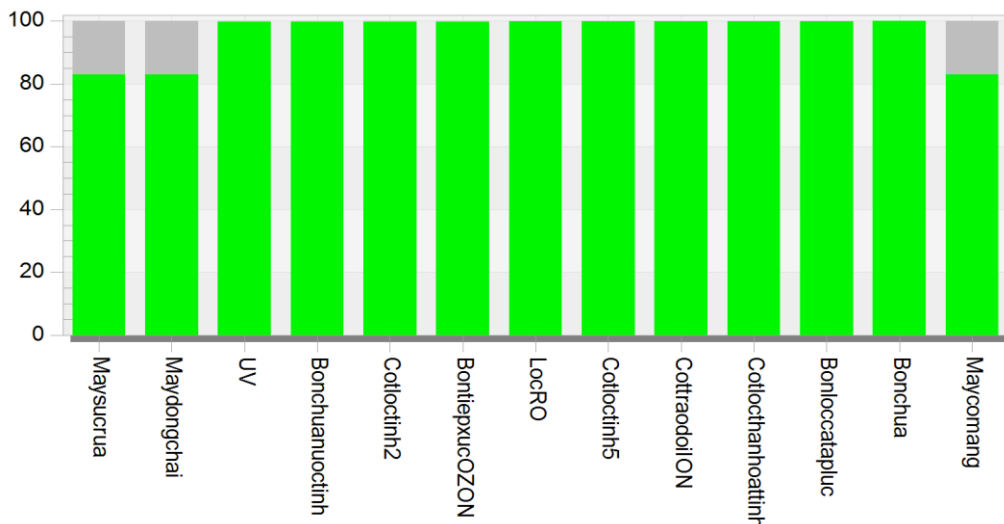


Fig. 3. Chart of Efficiency for Purified Drinking Water Production Processes

In addition, further optimization of pallet transportation between the packaging area and finished goods warehouse—through shorter transport routes or the use of automated guided vehicles (AGVs)—would further reduce internal logistics costs and improve the flexibility of the production system.

V. CONCLUSION

This study has developed and optimized the facility layout for a purified drinking water production plant with a capacity of 4000 L/h using the CORELAP method combined with system simulation in Tecnomatix Plant Simulation. Based on process data, the From-To matrix, and technical criteria, a REL chart was established, the Total Closeness Rating (TCR) was calculated, and the priority sequence for arranging functional areas within the plant was determined. The results show that the RO, ozone, fine filtration, and filling sections have the highest interrelationship levels and are therefore located in the central area to optimize material flow and reduce internal transportation distances.

The optimized CORELAP-based layout reduces the total internal transportation distance from approximately 106 m to 51 m, corresponding to a reduction of about 51.9% compared with the traditional layout. At the same time, space utilization efficiency increases from about 65% to 85%, and material flow

intersections in the main production area are almost completely eliminated. The production process is organized in a continuous one-way flow from raw water treatment to filling and packaging, thereby reducing waiting time and improving system stability.

Simulation results using Tecnomatix Plant Simulation show that the system operates stably over a simulation period of 3770 hours with a total output of approximately 754,557 finished bottles. The main equipment utilization ranges from 70% to 90%, with the RO unit and filling section identified as the main bottlenecks of the production line. The deviation between simulation results and theoretical calculations is small, confirming the accuracy and reliability of the proposed facility layout design.

This study has strong practical significance for the design and improvement of facility layouts in medium- and large-scale purified drinking water plants, contributing to reduced internal transportation costs, improved productivity, and optimized space utilization. Future research may extend this work by integrating advanced optimization algorithms such as Genetic Algorithm (GA), CRAFT, or Digital Twin models to enhance dynamic optimization capability and adaptability to real production changes.

REFERENCES

- [1]. Wang, J., et al. "Global Trends in Bottled Water Industry Development." *Journal of Cleaner Production*, vol. 312, 2021, pp. 127–139.
- [2]. Li, X., and Chen, Y. "Sustainable Manufacturing in Beverage Production Systems." *Resources, Conservation and Recycling*, vol. 164, 2021.
- [3]. Tompkins, J. A., et al. *Facilities Planning*. Wiley, 2010.
- [4]. Heragu, S. S. *Facilities Design*. CRC Press, 2018.
- [5]. Hassan, M. M., et al. "Limitations of Traditional Layout Planning Methods in Manufacturing Systems." *International Journal of Production Research*, vol. 59, 2021.
- [6]. Ponnambalam, S. G., et al. "Material Flow Optimization in Industrial Layout Design." *Computers & Industrial Engineering*, vol. 145, 2020.
- [7]. Yang, T., and Kuo, Y. "Optimization Techniques in Facility Layout Problems." *European Journal of Operational Research*, vol. 274, 2019.
- [8]. Muther, R. *Systematic Layout Planning*. Management & Industrial Research Publications, 1973.
- [9]. Bangsow, S. *Tecnomatix Plant Simulation: Modeling and Simulation of Logistics Systems*. Springer, 2015.
- [10]. Hassan, A., et al. "Integrated Facility Layout and Simulation Approach." *Simulation Modelling Practice and Theory*, vol. 102, 2020.
- [11]. [Abdinnour-Helm, S., et al. "Advanced Layout Design in Modern Manufacturing Systems." *Journal of Manufacturing Systems*, vol. 45, 2017.
- [12]. Drira, A., et al. "Facility Layout Problems: A Survey." *Annual Reviews in Control*, vol. 31, 2007.