International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 5 [May. 2024] PP: 247-256

Simulation of 8K Pulishing Production Lines by Tecnomatix Plant Simulation

Tuan Anh L., Dung N. V., *Quyen N. D.
Hanoi university of industry, No. 298 Cau Dien Street, Bac Tu Liem District, Hanoi, Vietnam.
Corresponding author: Quyennd9@Viettel.com.vn

ABSTRACT
Effective management of production processes is the cornerstone of success for any manufacturing endeavor. It involves meticulous planning, precise execution, and continuous improvement. By forecasting demand accurately, scheduling production activities efficiently, and optimizing resource allocation, organizations can minimize waste and maximize productivity. Implementing lean manufacturing principles facilitates the elimination of inefficiencies and the enhancement of workflows, resulting in streamlined operations and cost savings. Additionally, embracing advanced technologies empowers organizations to monitor production processes in real-time, identify bottlenecks, and make data-driven decisions for optimization. Moreover, fostering a culture of collaboration and communication among team members promotes innovation and problem-solving, while a steadfast commitment to quality ensures customer satisfaction and competitive advantage. In essence, effective management of production processes is paramount for achieving operational excellence and driving sustainable growth in today's dynamic manufacturing landscape.

KEYWORDS: *Tecnomatix Plant Simulation, Modeling, Polishing Line*

Date of Submission: 14-05-2024 Date of acceptance: 25-05-2024

I. Introduction

The development of the market demands that businesses continuously improve their production processes to meet the increasingly diverse and evolving needs of customers. As the market expands or consumer trends change, businesses must quickly adapt and provide new products and services that meet requirements for quality, price, and system performance.

To cope with market developments, businesses must continually improve their production processes. This may involve optimizing current processes, investing in new technologies to enhance efficiency, and improving supply chain processes to reduce time and costs. By using data and statistical figures, managers can measure productivity, waste rates, and waiting times to identify improvement opportunities and issues. However, to achieve success in optimizing the polishing line, manufacturers need to consider multiple factors. Understanding and accurately assessing these factors help predict and respond flexibly and effectively, thereby optimizing production processes and enhancing the overall performance of the steel polishing line [1].

Tecnomatix Plant Simulation is an advanced manufacturing management simulation software developed by Siemens [2]. Built on the Siemens Digital Industries Software platform, Tecnomatix Plant Simulation is a versatile tool used to create detailed digital models of production lines, from planning and scheduling to actual operation. With the ability to simulate both large and complex manufacturing systems, Tecnomatix Plant Simulation allows businesses to conduct detailed analysis and predict production performance before implementing actual changes, including machinery, equipment, personnel, and work processes [3]. In this way, users can test and optimize various variants of the production line before making changes in the real environment. This helps minimize risks and costs associated with testing and implementing production improvements.

Furthermore, Tecnomatix Plant Simulation provides powerful analysis features to assess the performance and efficiency of manufacturing lines. From analyzing workflow to evaluating workloads and optimizing production schedules, this software offers intelligent tools to assist managers in making strategic decisions and optimizing production operations [5].

II. Setup and method

2.2 Current State of Production

The system is designed with two separate production and processing lines, each capable of handling four common types of steel including CT3, CT35, SPCC and SS400, Figure 1. These steel types vary in thickness, ranging from 0.6 mm, 0.8 mm, 1 mm, 1.2 mm, 1.4 mm, 1.6 mm, 1.8 mm, 2 mm, 2.2 mm, 2.4 mm, 2.6

mm, 2.8 mm to 3.0mm, and in width, adhering to standards ranging from 1 000 mm, 1 200 mm, 1 500 mm, 2 000 mm to 2 500mm, creating a wide range for manufacturing and processing. This illustrates the flexibility of the system in meeting various production needs and requirements from customers. This flexibility allows for swift and adaptable response to market and customer demands. However, this diversity also comes with challenges in management and coordination to ensure efficient operation and optimal resource utilization.

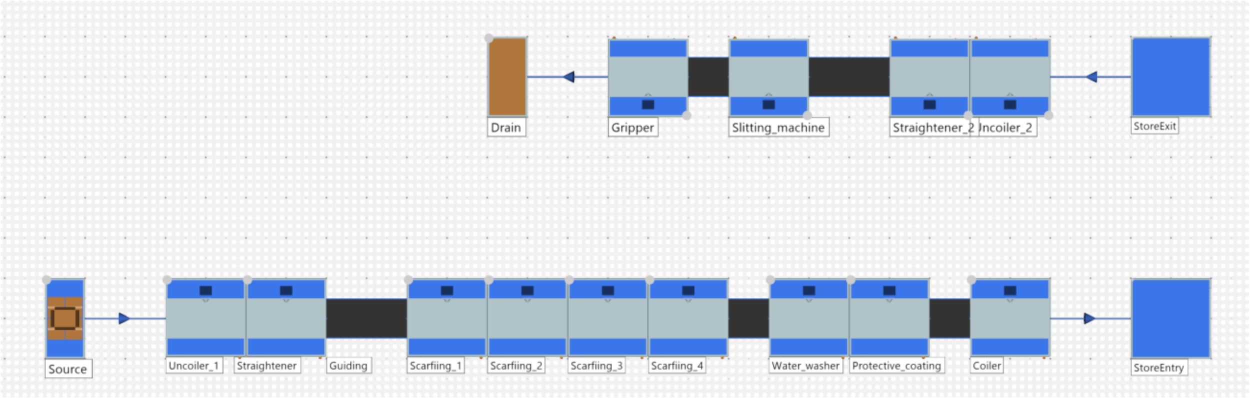


Figure 1. Modeling of Process

After inputting data into the simulation, the research team observed that the production line's performance was not optimal due to the frequent need to adjust machine settings for each different order. This is largely attributed to variations in the types of steel used and their technical specifications such as thickness and width. This not only increases waiting times and reduces overall production efficiency but also escalates maintenance and operational risks.

Furthermore, the production system faces the issue of interruptions caused by being split into two separate lines. While the initial purpose of this division was to accommodate diverse manufacturing requirements from various clients, it inadvertently imposes a series of constraints. This fragmentation not only disrupts the production process but also hampers the optimization of the assembly line and prolongs processing times for other orders. Consequently, it introduces a range of challenges in managing and operating the system, diminishing flexibility and precision in the manufacturing process.

2.2 Optimized method of solution

In the decision-making process of selecting suitable machinery for a production line, employing the Analytic Hierarchy Process (AHP) [14] lends professionalism and solid theoretical foundation. AHP is a quantitative method proven to be effective, aiding in evaluating and ranking factors according to their importance and priority. In this process, critical criteria such as machine technical specifications, performance, speed, control ability and operational costs are identified and systematically assessed. By analyzing and comparing these factors, AHP provides businesses with an objective and comprehensive view, facilitating decisions based on logical reasoning and empirical data.

Moreover, utilizing AHP in decision-making minimizes bias and enables logical and objective conclusions. The steps within AHP, including establishing a hierarchical structure, determining weights for criteria, and conducting pairwise comparison analysis, create a clear and logical system. As a result, the final decision is based on transparent data and information, enhancing objectivity and effectiveness in the machinery selection process for the production line.

The criteria comparison matrix often relies on expert opinions, but two main concerns arise. Firstly, it's susceptible to subjective opinions of decision-makers. For instance, while one may deem criterion X1 more important than X2, the extent of this importance varies among individuals. Secondly, ensuring data consistency is crucial. If X1 is considered twice as important as X2 and X2 is deemed three times as important as X3, theoretically, X1 should be six times as important as X3. However, real-world expert opinions may not align with this logic due to their inability to grasp the entirety of the comparison matrix's logic. Therefore, striving for objectivity in evaluations while acknowledging inherent subjectivity remains pivotal.

The evaluation weights of each element corresponding to the comparison set are determined by [8]:

$$\alpha_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{1}$$

We need to compare the CI (Consistency Index) value, which indicates the degree of inconsistency, with the appropriate RI (Random Index) depending on the matrix order using the formula [8]:

$$CR = \frac{CI}{RI} \qquad (2)$$

If the CR (consistency ratio) is less than 0.1, the matrix is considered consistent and proceeds to the next step to establish the priority of elements in the hierarchical tree. Alternatively, you may need to adjust your evaluations to make the matrix more consistent. They represent the linkage of weights within each element at each level, Table 1. Finally, they aggregate the calculation results and draw the final conclusion about the selected option.

Table 1. Summary of machine selection

RANK	UNCOILER	SCARFING MACHINE	SLITTING MACHINE
NO.1	Wattage	Reflectance	Trimming allowance
NO.2	Load capacity	Control Ability	Flexibility
NO.3	Speed	Speed	Speed
NO.4	Control Ability	Wattage	Wattage
NO.5	Price	Price	Price
NO.6	Machine Space	Machine Space	Machine Space

III. Results And Discussion

3.2.1 *Production Line Optimization Methods*

To optimize the production line, specific measures can be implemented with the aim of enhancing efficiency and effectiveness. Firstly, the utilization of a straight-line conveyor is a common method to save factory space and optimize material flow. Well-organized coordination among production steps helps minimize waiting times and strengthens the ability to respond swiftly to market demands. Secondly, selecting fixed types of steel based on specific technical factors such as hardness, thickness, and processing characteristics is key to optimizing the production process and minimizing error risks. Lastly, adjusting the conveyor speed to match specific system requirements will optimize overall performance and ensure the stability and reliability of the production process. When executed judiciously and professionally, these measures will enhance the performance and efficiency of the steel production line, Figure 2.

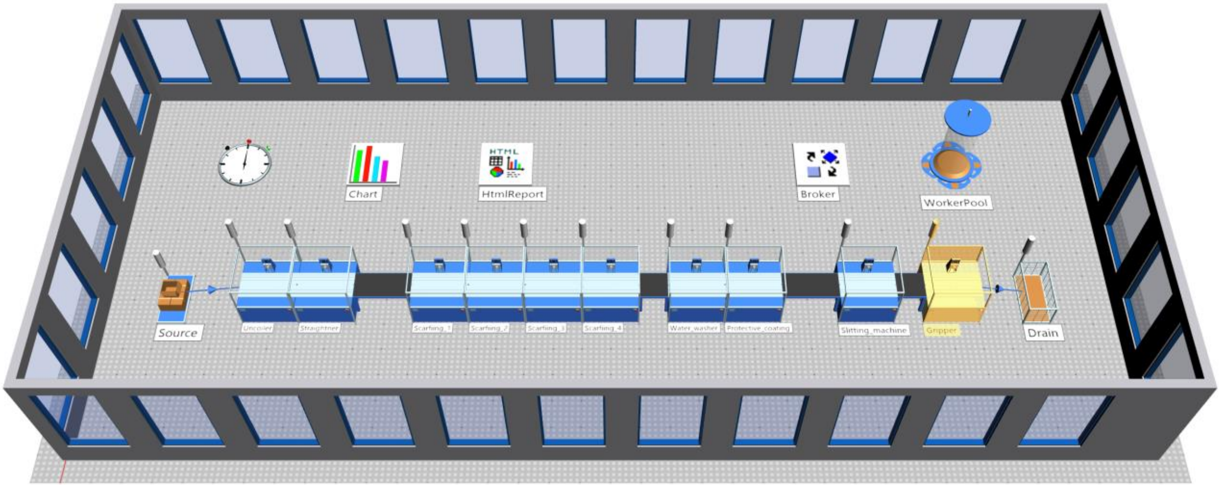


Figure 2. Display of a manufacturing plant in the simulation software Tecnomatix Plant Simulation

Transforming two separate assembly lines into one straight line brings several significant benefits to manufacturing businesses. Firstly, it helps reduce machinery and maintenance costs. Instead of maintaining and operating two separate systems, using a single straight line reduces the number of necessary machines and lowers annual maintenance costs[8]. This creates favorable conditions for focusing resources on core production activities and reduces risks associated with maintaining multiple systems.

Secondly, by optimizing the production process on a single line, businesses can enhance productivity and product quality. This concentration also facilitates continuous improvements and enhances the efficiency of the production process.

Lastly, organizing a single straight line also optimizes workshop floor space. Instead of allocating space for two separate lines, using a single straight line optimizes workspace layout, thereby enhancing the efficient utilization of floor space and minimizing risks associated with inefficient space usage. Overall, this transformation not only helps businesses save costs but also strengthens competitiveness and production efficiency.

Selecting the right type of fixed steel based on specific technical factors such as hardness, thickness, and machining properties is key to optimizing the manufacturing process and minimizing the risk of errors. Each type of steel possesses unique characteristics that can significantly impact production efficiency and product quality. For instance, the hardness of the steel determines its resistance to wear and tear during machining processes, while thickness affects its structural integrity and suitability for particular applications. By carefully considering these technical factors, manufacturers can choose the most suitable type of steel for their production needs, ensuring smoother operations and reducing the likelihood of defects or errors, Table 2.

Steel Grade	*Carbon content (% C)*	*Elongation*	*Tensile Strength (MPa)*	*Application*
CT3	<0.25%	22% - 26%	373 – 690	Used for manufacturing construction steel, hot rolled coil steel, structural steel, and machine parts [15].
CT35	<0.39%	20% - 26%	480 – 630	Used in the production of machine parts, precision engineering, and load-bearing structures [13].
SS400	<0.22%	20% - 24%	400 – 510	Used for manufacturing construction steel, hot rolled coil steel, structural steel, and machine parts [10].
SPCC	<0.15%	28% - 33%	270 - 390	Used for manufacturing galvanized, steel pipes, structural steel, machine parts, and household appliances [12].

Table 2. Comparison table for choosing the right type of steel

The properties of CT3 and CT35 steel both include high ductility and good formability due to their carbon content ranging from below 0.25% to 0.39%. However, both types of steel have lower hardness and strength compared to other steel grades.

SS400 is a type of medium carbon steel known for its flexibility, high strength, and good load-bearing capacity. Its surface has a dark blue color and is prone to yellow surface rusting over a short period when exposed to natural environments unless using protective measures such as oil coating, painting, or zinc plating are not applied.

SPCC steel plate has strong impact resistance and processing capabilities, helping to maintain stable mechanical properties. It is easily bendable, slittable, whitened, and shaped, allowing for the creation of various shapes and sizes according to application requirements. Cold-rolled SPCC steel exhibits good oxidation and corrosion resistance, helping to maintain high performance and durability in harsh environments [4].

The research team utilizes four common types of steel for simulation and analysis. Each type of steel possesses different technical characteristics suitable for specific applications, facilitating observation during processing.

Adjusting the speed of the production line to meet specific system requirements is an essential method for optimizing overall production efficiency. In doing so, not only does it increase production output, but it also ensures the stability and reliability of the process. This speed adjustment can be based on factors such as product volume, completion time, and quality requirements. When the speed is accurately adjusted, the system operates more efficiently, minimizing waste and enhancing the ability to quickly respond to changing production requirements. This plays a crucial role in ensuring that products meet the highest quality standards while optimizing the overall efficiency of the production system.

The Taguchi matrix helps optimize the factors and parameters of a process or product to achieve the best performance. By applying the Taguchi matrix, you can optimize factors to minimize variability and defects, thereby improving the quality of the product or service. The Taguchi matrix allows you to identify which factors have the greatest impact on the desired outcome and prioritize them for focused improvement efforts. Applying the Taguchi method to construct an L16 matrix, Table 3 and Figure 3.

The application of a comprehensive and standardized production system is crucial for a business to achieve success. By combining a perfected system with standardization, enterprises can optimize manufacturing processes, enhance product quality, and strengthen competitiveness in the market. Moreover, implementing standardized systems in research and production helps businesses achieve consistency and stability in manufacturing, ensuring that products meet quality requirements and standards.

Through experimentation, it was observed that the machining speed is influenced by the hardness of each type of steel. Additionally, varying thicknesses and widths of steel also significantly affect the overall machining speed due to congestion from the coiling process and scratches, resulting in uneven output.

Table 3. Experiment results

No.	Real value			Time (h)	Quantity (m)	
	Steel grade	Thinkness (mm)	Width (m)		Simulation	Actual
1	CT3	1.2	2.5	24	5393	5445
2	CT3	1.0	2	24	6770	6780
3	CT3	0.8	1.5	24	8222	8300
4	CT3	0.6	1	24	8854	8745
5	CT35	1.2	1	24	6762	6670
6	CT35	1.0	1.5	24	7186	7045
7	CT35	0.8	2	24	7667	7550
8	CT35	0.6	2.5	24	8216	7985
9	SS400	1.2	2	24	6248	6235
10	SS400	1.0	2.5	24	6608	6650
11	SS400	0.8	1	24	9276	9210
12	SS400	0.6	1.5	24	10091	10080
13	SPCC	1.2	1.5	24	6763	6800
14	SPCC	1.0	1	24	8214	8250
15	SPCC	0.8	2.5	24	7667	7700
16	SPCC	0.6	2	24	9587	9600

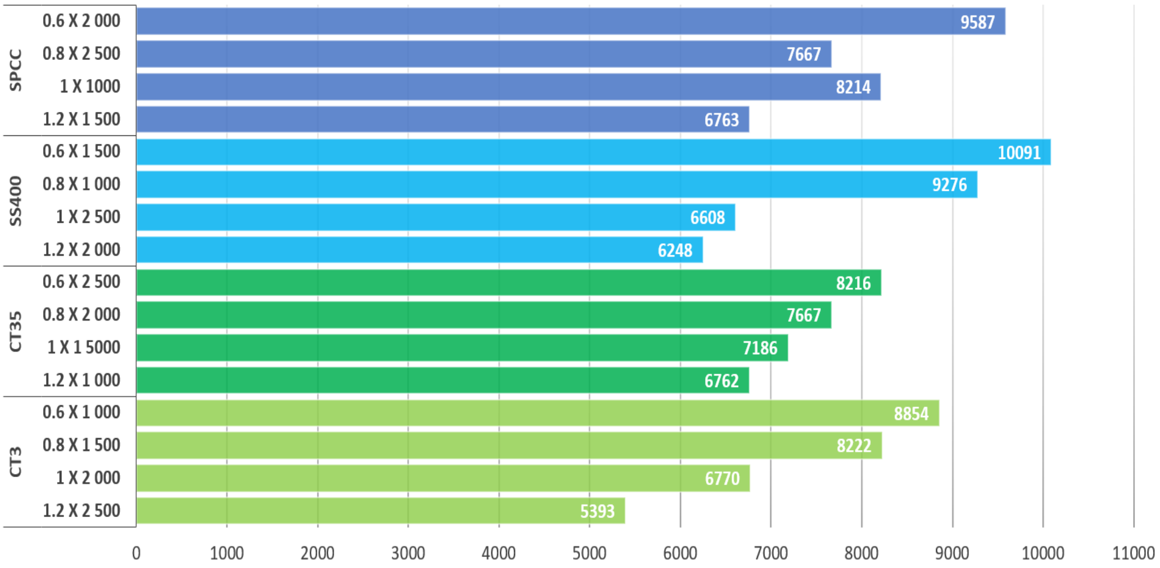


Figure 3. Machine output comparison chart after Simulating

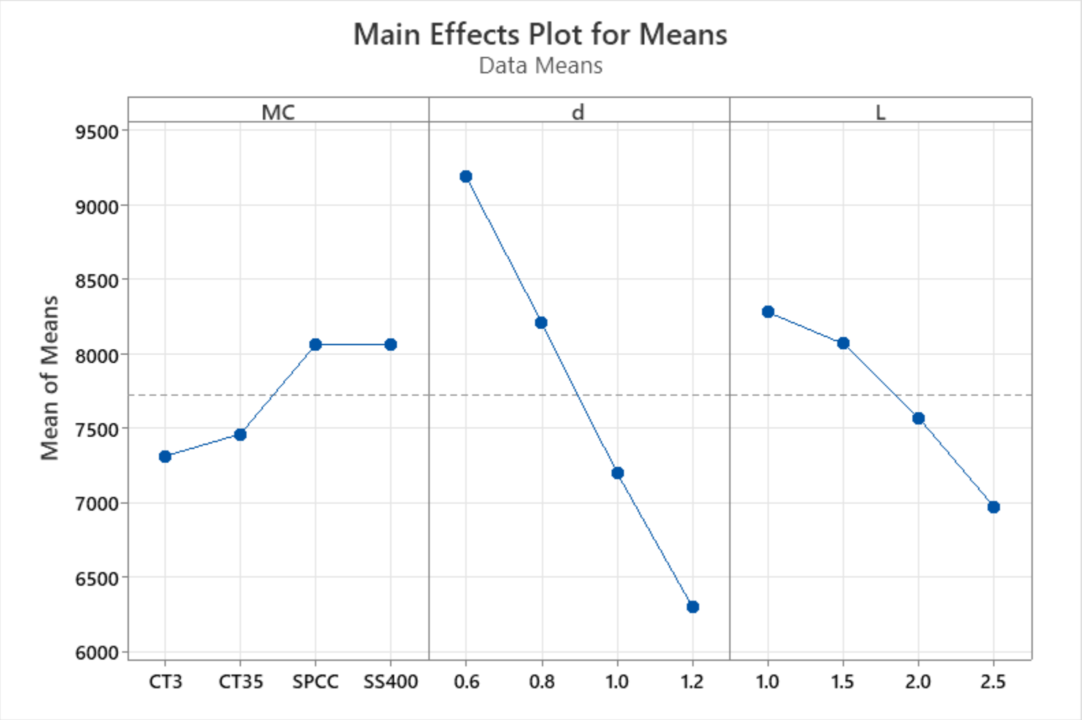


Figure 4. Influence of input information on polishing quantity

Based on the Figure 4, we can analyze the results as follows: when the two steel grades are SPCC and SS400, they will have equivalent output. As the thickness of the steel increases, the output decreases, and as the width of the steel increases, the output decreases.

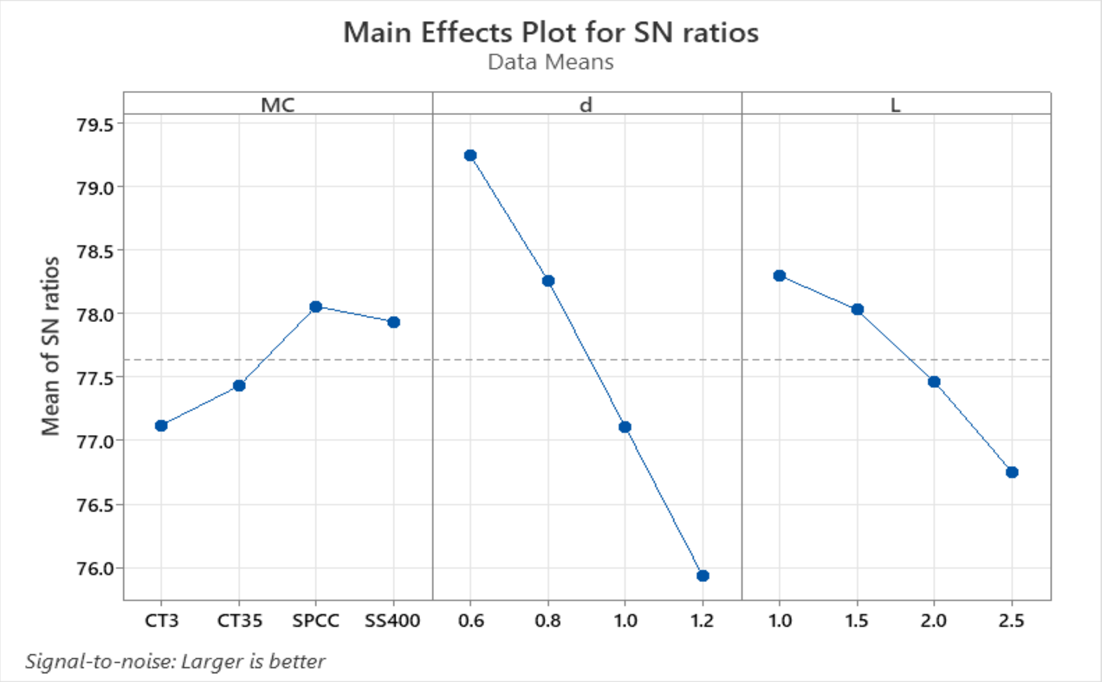


Figure 5. Main effects plot for S/N ratios

Based on the analysis Figure 5, we can see that for the SPCC steel grade, a thickness of 0.6 mm and a width of 1 meter are the optimal values to achieve the highest output.

When combined with the production results from the VMC Corporation, we compare the corresponding results between simulation and reality. For the CT3 steel grade, the actual output increased by about 2%, while for the CT35 grade, it decreased by 1.66%. The SPCC and SS400 steel grades showed similar output levels.

According to the production experimentation results, our team has discerned that the processing time per meter of steel varies depending on the steel type, thickness, and width. Particularly noteworthy is the observation that, compared to CT3 steel with a thickness of 1.2 mm and a width of 2 500 mm, the overall processing time for SS400 and SPCC steels is reduced. This underscores the distinct material properties of these steel types, attributed to variations in carbon content.

Furthermore, each 0.2 mm reduction in thickness corresponds to approximately a 10% decrease in the overall processing time of the production line. Additionally, alterations in steel width affect the operational time of coil Uncoiler and Scarfing machines. These factors directly impact the processing time for each order and the average output of the enterprise.

These insights gleaned from analysis offer opportunities for efficiency enhancements and process optimization. By minimizing processing time and bolstering output, the enterprise can achieve heightened productivity and competitiveness in the market.

3.2.2 Developing Factory Layout Models

The analysis and arrangement of factory layout play a crucial role in optimizing workflow and minimizing potential risks during operation, while ensuring flexibility to accommodate changes and improvements in the future, Figure 5. By carefully organizing the space and designing production models accurately, we can optimize the movement of materials and products, reduce waiting times, and enhance overall efficiency[6]. Additionally, this analysis helps identify and mitigate risks that may arise during operations, from raw material handling to finished product manufacturing. Importantly, designing a flexible layout ensures that the factory can adapt to changes and improvements in the future effectively without compromising the efficiency of the production process, Table 4.

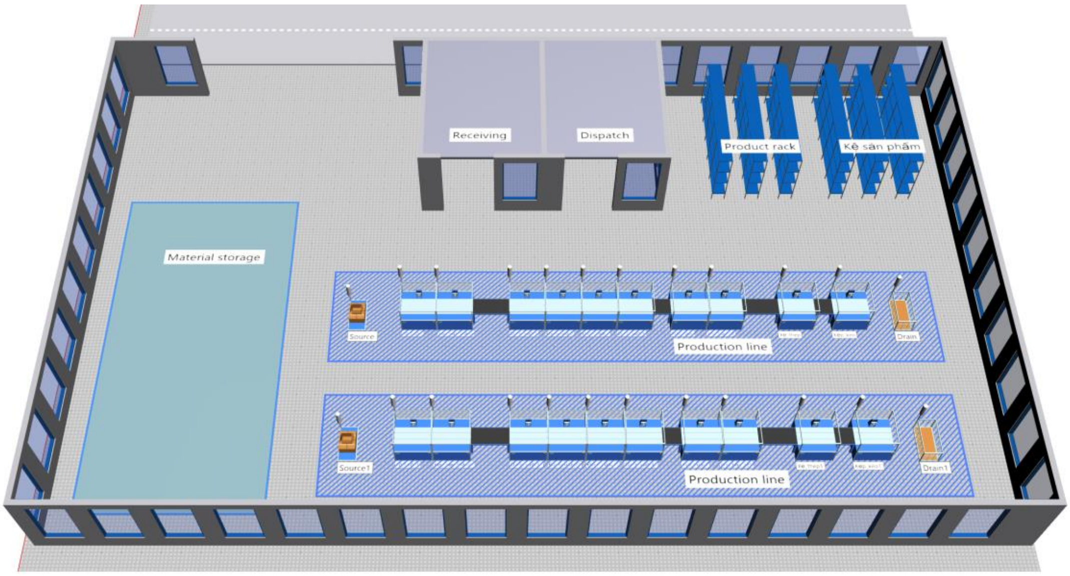


Figure 5. Factory Layout Model design

Table 4. Area area and material movement flow

Department	Area (m^2)	Next Department	Flow (m)
Receiving	120	Material storage	25
Material storage	584	Production Line	20
Production Line	1360	product rack	25
product rack	280	Dispatch	25
Dispatch	120		

IV. Future system

The model was concluded through data analysis and real-world results at the Viettel Manufacturing Equipment Corporation's factory. The research team has drawn conclusions about the model and the data to build a factory for future production, aiming to achieve mass production with a maximum output of 55,000 to 65,000 units per month, as illustrated in figure 8.

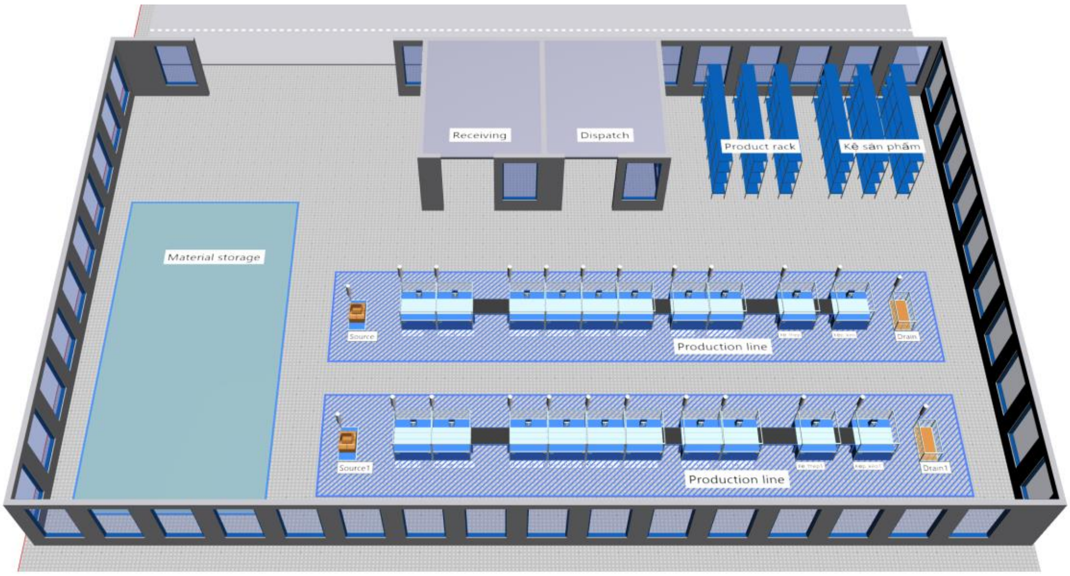
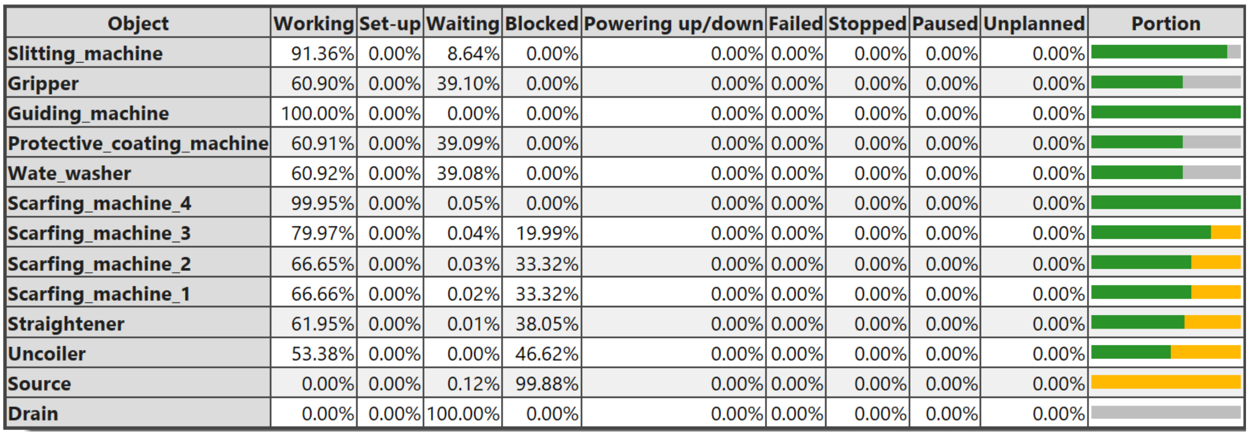


Figure 6. Future factory model

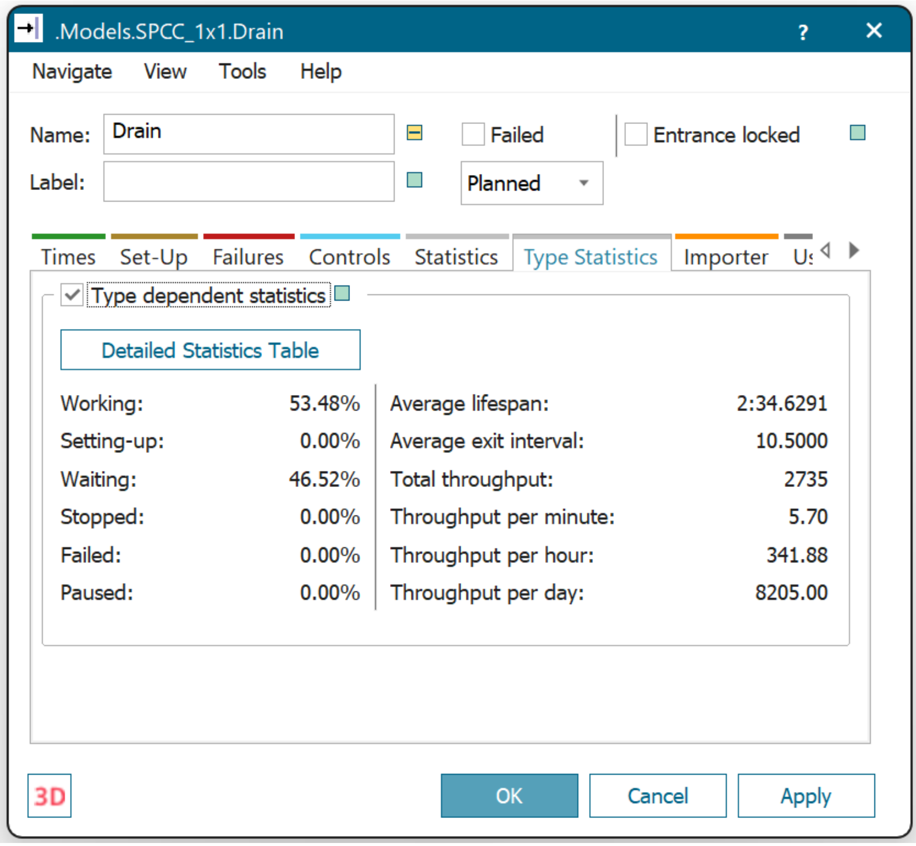


Object	Working	Set-up	Waiting	Blocked	Powering up/down	Failed	Stopped	Paused	Unplanned	Portion
Slitting_machine	91.36%	0.00%	8.64%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩⬜
Gripper	60.90%	0.00%	39.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩⬜
Guiding_machine	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩
Protective_coating_machine	60.91%	0.00%	39.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩⬜
Wate_washer	60.92%	0.00%	39.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩⬜
Scarfing_machine_4	99.95%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩
Scarfing_machine_3	79.97%	0.00%	0.04%	19.99%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩🟨
Scarfing_machine_2	66.65%	0.00%	0.03%	33.32%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩🟨
Scarfing_machine_1	66.66%	0.00%	0.02%	33.32%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩🟨
Straightener	61.95%	0.00%	0.01%	38.05%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩🟨
Uncoiler	53.38%	0.00%	0.00%	46.62%	0.00%	0.00%	0.00%	0.00%	0.00%	🟩🟨
Source	0.00%	0.00%	0.12%	99.88%	0.00%	0.00%	0.00%	0.00%	0.00%	🟨
Drain	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	⬜

Figure 7. Machine operating time and congestion

Table 5. Process data

Process	Time (s)
Source	5.2
Uncoiler	4.8
Straightener	5.2
Guiding machine	5.2
Scarfing machine 1	6
Scarfing machine 2	6
Scarfing machine 3	7.2
Scarfing machine 4	9
Water washer	5.2
Protective coating machine	5.2
Slitting machine	7.8
Gripper	5.2



Name: Drain
Label:
☐ Failed
☐ Entrance locked
Planned
☑ Type dependent statistics

Working:	53.48%	Average lifespan:	2:34.6291
Setting-up:	0.00%	Average exit interval:	10.5000
Waiting:	46.52%	Total throughput:	2735
Stopped:	0.00%	Throughput per minute:	5.70
Failed:	0.00%	Throughput per hour:	341.88
Paused:	0.00%	Throughput per day:	8205.00

Figure 8. Simulation result

- Production rate: 10.5 (s/m)
- Throughput 1 day: 2735 (m)
- Throughput 1 month: 55000 to 65000 (m)

Based on these results, we can infer that on average, a 1-meter piece can be completed in approximately 10.5 seconds. Consequently, the daily production throughput reaches 2,735 meters. With 265 working days in a year, the annual production throughput would amount to 724,775 meters[9], Fig 6.

Through meticulous research, our team has provided detailed analysis and evaluation of the steel polishing production line, enabling businesses to select appropriate production processes and materials with evidence gathered from experimental results and feasibility analyses.

In addition, through specific research processes, we have identified the causes of obstacles and waste in the production process. This has allowed us to propose specific and feasible solutions to improve production efficiency. By using evidence from real-world scenarios and careful examination, we have provided valuable actionable advice to businesses, aiding in their development and enhancing competitiveness in the market. This reflects our commitment to providing detailed and quality information to support decision-making and sustainable development for businesses.

V. Conclusion

Analysis of past applications of Tecnomatix Plant Simulation for modeling and simulating polishing processes demonstrates its efficiency as an IT tool for enhancing the productivity of existing systems. Optimization of resource consumption, inventory management, and production time are central objectives of leveraging Tecnomatix Plant Simulation.

When researching the project, we consistently adhered to the initial objectives set out to achieve the best results. After the working process, the following achievements have been obtained:

- Calculated and designed industrial systems for manufacturing workshops and product processing.
- Optimized the manufacturing workshop system, helping the enterprise save maximum time and costs and increase labor productivity throughout the production process.
- Calculated, designed, and optimized the industrial system for the conveyor belt line.
- Successfully built models, algorithm simulation programs on software, and compared simulation results with real-world results to determine parameters for optimizing the production system.

The project is highly feasible and meets real-world needs. If applied in production, it will reduce production and operational costs, increase labor productivity, and enable the enterprise to achieve higher profits. Additionally, it can optimize product costs to enhance competitiveness in the market. Therefore, we recommend the enterprise to consider allowing us to implement the project in the workshop to validate the results and further improve them to deliver the best outcomes. With collaboration and attention from the enterprise and the application of the project's results, we believe it will bring the highest benefits to the business.

References

[1]. Gregor M., Medvecky S., Application of digital engeenering and simulation in the design of products and production systems, Management and Production Engineering Review, 1, 1, 71–84, 2010

[2]. S. Bangsow, Tecnomatix Plant Simulation: Modeling and Programming by Means of Examples. Springer-Verlag Berlin Heidelberg, 2020

[3]. Palajova S., Figa S., Gregor M., Simulation of manufacturing and logistics systems for the 21-th century, Simulation, emulation, metamodelling, cloud computing, 7, 2, 47–60, 2012

[4]. Chien-hung lin, Jia-Ren Lee, Characterization Of SPCC Steel Stress Behaviour In Brine water Environment International Journal of Electrochemical Science, 2019

[5]. Milan J., Modeling with technomatix plant simulation International Journal of SimulationModeling, 2017,11 12-5

[6]. Pekarcikova, M.; Trebuna, P.; Kliment, M.; Dic, M. Solution of Bottlenecks in the Logistics Flow by Applying the Kanban Module in the Tecnomatix Plant Simulation Software. Sustainability 2021, 13, 7989. https://doi.org/10.3390/su13147989.

[7]. Longo, C.S.; Fantuzzi, C. Simulation and optimization of industrial production lines. At-Automatisierungstechnik 2018, 66, 320–330.

[8]. Edjossan-Sossou, A.M.; Galvez, D.; Deck, O.; Al Heib, M.; Verdel, T.; Dupont, L.; Chery, O.; Camargo, M.; Morel, L. Sustainable risk management strategy selection using a fuzzy multi-criteria decision approach. Int. J. Disaster Risk Reduct. 2020, 45, 101474.

[9]. Derradji, R.; Hamzi, R. Multi-criterion analysis based on integrated process-risk optimization. J. Eng. Des. Technol. 2020, 18, 1015–1035.

[10]. https://stavianmetal.com/thep-ss400/

[11]. https://4dsysco.com/what-is-plant-simulation

[12]. https://vntec.com.vn/thep-can-nguoi-spcc-sd-jis-g-3141/

[13]. https://thepphongduong.com/san-pham/thep-c35-thep-s35c/

[14]. https://bis.net.vn/forums/t/2415.aspx

[15]. https://www.nguyennguyenhungsteel.com/cam-nang-kien-thuc/so-sanh-thep-ct3-va-ss400.html