A Simulation-Based Optimization Approach for Furniture Manufacturing Using AnyLogic Software

Tối ưu hóa dựa trên mô phỏng trong ngành sản xuất đồ nội thất bằng phần mềm AnyLogic

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Abstract: This paper presents the application of discrete-event simulation to optimize resource utilization at a furniture manufacturing enterprise in Vietnam. Based on field surveys and collected production data, the research developed a simulation model using AnyLogic software. The study determined the optimal solution by changing the number of resources. The simulation results show that the optimal solution is much more effective than the current one, with the enterprise's resource utilization reaching 96.7%. The study also contributes to providing an effective decision support tool, suitable for the context of digital transformation in manufacturing.

Keywords: *AnyLogic; Furniture Manufacturing; Optimization; Simulation*

Tóm tắt: Bài báo trình bày quá trình ứng dụng mô phỏng dựa trên sự kiện rời rạc nhằm tối ưu hóa mức độ sử dụng tài nguyên tại một doanh nghiệp sản xuất đồ nội thất tại Việt Nam. Thông qua quá trình khảo sát thực tế và thu thập dữ liệu sản xuất, nhóm nghiên cứu đã xây dựng mô hình mô phỏng bằng phần mềm AnyLogic. Sau đó thử nghiệm các kịch bản khác nhau bằng cách thay đổi về số lượng nguồn lực, từ đó xác định phương án tối ưu. Kết quả mô phỏng cho thấy phương án tối ưu mang lại hiệu quả vượt trội so với hiện tại, mức độ sử dụng tài nguyên của doanh nghiệp đã lên tới 96.7%. Nghiên cứu cũng góp phần cung cấp một công cụ hỗ trợ ra quyết định hiệu quả, phù hợp với xu hướng chuyển đổi số trong lĩnh vực sản xuất trong nền công nghiệp hiện đại.

Từ khóa: *Phần mềm AnyLogic; Ngành sản xuất đồ nội thất; Mô phỏng; Tối ưu hóa*

1. Introduction

According to statistics from the Center for Industrial Studies (CSIL), in 2023, Vietnam ranked 6th in global furniture production. The average annual growth rate of furniture production is 10% and furniture exports is 11%, ranking second in Asia. According to data from the Vietnam Forestry Administration, furniture accounted for 82.9% of the total export turnover of wood and wood products in 2022, reaching nearly 8.4 billion USD (Figure 1) [1]. Therefore, the furniture manufacturing industry plays a very important role in the Vietnamese economy.

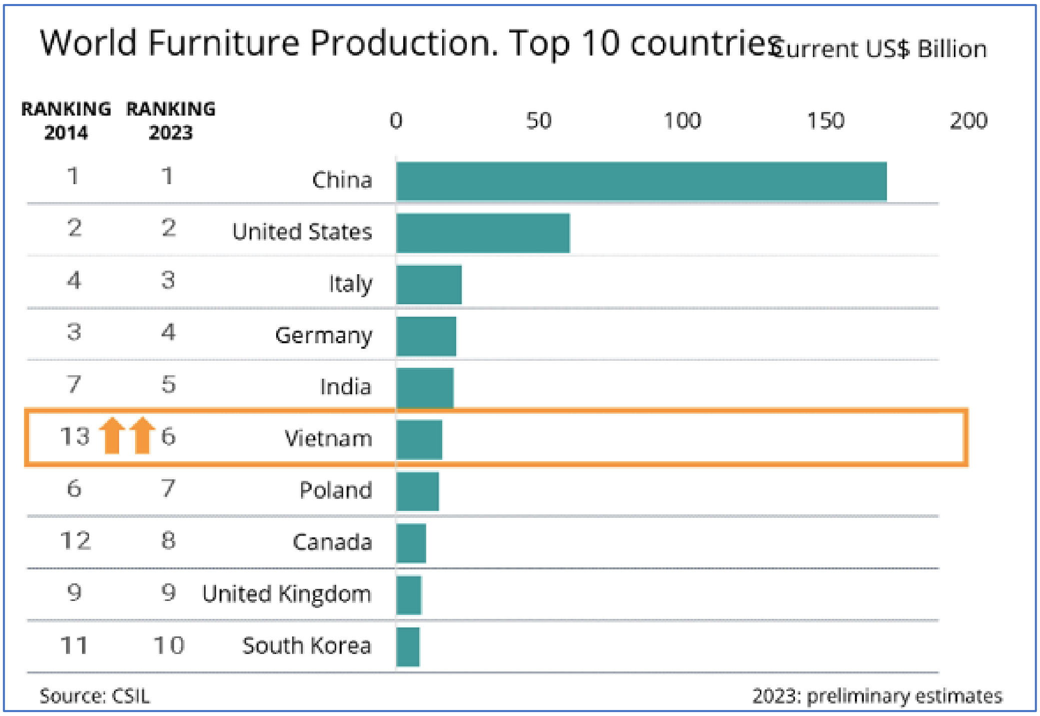

Figure 1. Top 10 furniture production countries in the world

Besides, the furniture manufacturing industry in Vietnam is expected to grow strongly in both domestic and export markets because of abundant raw materials, cheap labor and increasing furniture consumption [2], [3].

However, in the context of sustainable economic development, the furniture industry is facing the need to improve production processes to reduce costs, increase productivity and reduce environmental impact [1]. Therefore, businesses need to quickly apply advanced technologies such as simulation and production optimization.

AnyLogic software is considered one of the best simulation tools, especially suitable for production. It helps businesses easily evaluate, test different production cases and make optimal decisions to improve operational efficiency and minimize risks in production [4].

The objective of this study is to simulate the furniture manufacturing process of a furniture manufacturing company in Vietnam using AnyLogic software to evaluate and propose options for optimizing operational efficiency. The study focuses on analyzing workflow, processing time, and resource utilization efficiency. The research methodology includes data collection, production process simulation, and data analysis to determine the most optimal case.

The structure of the study consists of five parts. Part 1 presents an overview of the furniture manufacturing industry and the importance of simulation. The theoretical basis is presented in part 2. Part 3 focuses on describing the research methodology. Part 4 presents the simulation and optimization results. Finally, part 5 provides conclusions and recommendations.

2. Theoretical Background

2.1. Simulation

Simulation represents the operation of a process or system for the purpose of studying and evaluating its performance under varying conditions. While actual testing would be costly, risky, or impractical, simulation allows testing of a variety of scenarios safely and efficiently [5], [6]. It is a useful tool for forecasting, identifying bottlenecks, calculating resources and supporting decision making, especially in the case of process improvement or new plant establishment [7], [8].

Steps to build a simulation model, including [5]:

Step 1. Identify the problem.

Step 2. Determine the scale

Step 3. Collect data.

Step 4. Build and develop the model.

Step 5. Validate the model.

Step 6. Document the model for future use.

Step 7. Choose an appropriate design.

Step 8. Set up simulation conditions

Step 9. Run the simulation.

Step 10. Present the results.

Step 11. Recommend next actions.

Simulation includes: discrete simulation, continuous simulation, stochastic simulation, agent-based simulation, hybrid simulation. Depending on each different simulation case, the appropriate method will be selected [9].

2.2. AnyLogic Software

AnyLogic is a multi-method simulation software developed by The AnyLogic Company in the 2000s. The outstanding feature of this software is the ability to combine discrete event simulation, dynamic systems and agent-based simulation to bring the best simulation results. The software is widely used for simulation in the fields of manufacturing, logistics and supply chain, hospitals, transportation and customer service [4].

The software interface is very intuitive and flexible. The main interface includes functional areas such as workspace, palette, canvas, properties. Users can drag and drop simulation objects, set properties and link logic operations directly. In addition, AnyLogic also integrates a real-time simulator and output analysis tools, making it easy to control the simulation process (Figure 2) [4].

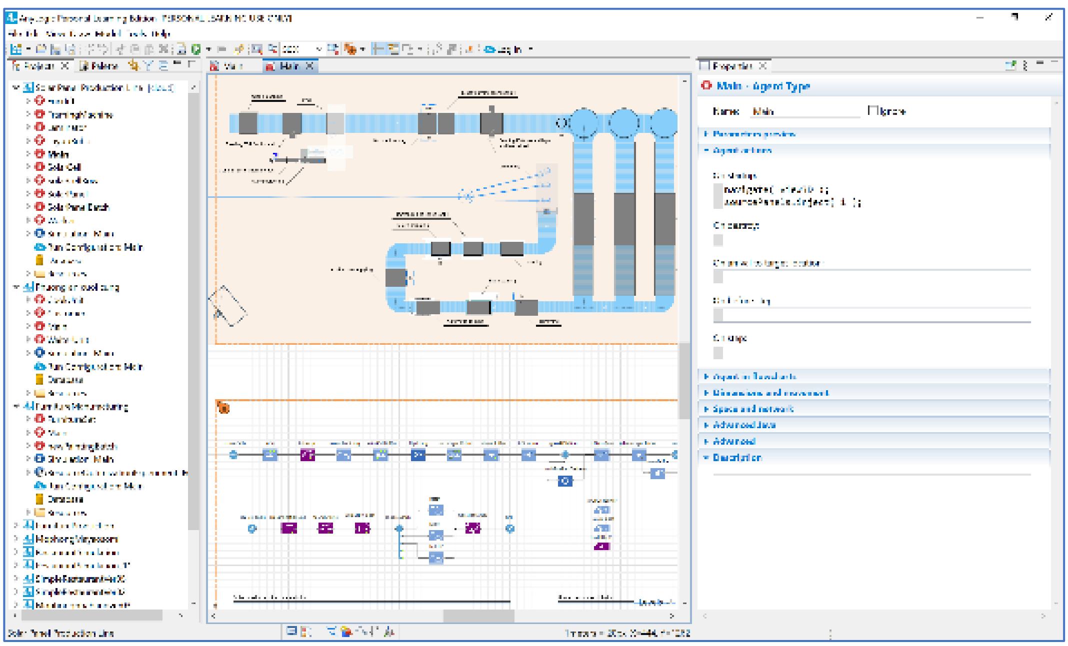

Figure 2. AnyLogic Software Interface

2.3. Literature review

In industry 4.0, simulation is a key tool to support decision making. Therefore, there are many studies applying simulation in smart manufacturing, logistics, healthcare and urban planning [10].

In 2023, Atikur Rahman et al. implemented a discrete event simulation model using AnyLogic to support decision-making, focusing on line balancing techniques to reduce bottlenecks, increase productivity, and reduce worker idle time [11].

In addition, another study used AnyLogic software to simulate the production line to identify the bottleneck process. Combined with the ECRS principle, the study identified an optimized line with high efficiency and production capacity [12].

A study by Ibrahim Cil et al. also used AnyLogic software to simulate and analyze the logistics system according to the Milk Run model to optimize the lean supply network. The results showed the ability to improve supply chain performance, reduce costs and improve transportation efficiency [13].

Besides, the coffee shop model was simulated by applying Reinforcement Learning with AnyLogic software through the Pathmind platform. The results showed that the study helped reduce customer service time and improve business performance [14].

In traffic management, in 2022, Yang Liu et al. used AnyLogic software to simulate and optimize traffic flow in a congested area in Tianjin. After performing 73 different simulations, the study found the optimal solution that reduced travel time from 145.46 seconds to 132.31 seconds [15].

In the medical field, in 2024, Yujie Wang uses AnyLogic software to simulate emergency department operations and propose solutions to improve the quality of medical care [16]. In 2023, Chuanxi Niu combined the YOLOv5s model and AnyLogic software to determine the optimal solution to make quick and accurate decisions (94.01%) in emergency situations [17]. In 2021, Jalal Possik et al. simulated COVID-19 transmission in Canada using AnyLogic software [18].

In addition, Tadej Kanduc et al. presented the optimization of the production process at a furniture company in Slovenia. The project was modeled using discrete event simulation, analyzed the current production system, developed an automated method, and proposed an effective optimization of the production process [19]. Moreover, Tadej Kanduc et al. presented the optimization of the production process at a furniture company in Slovenia. The project was modeled using discrete event simulation, analyzed the current production system, developed an automated method, and proposed an effective optimization of the production process [20].

Furthermore, the project to optimize the production process at a furniture manufacturing enterprise with a catalog of more than 30,000 products was also implemented by Blaz Rodic et al. The authors used a discrete event simulation model and an automation method based on order data. The results showed that the heuristic algorithm provided an optimal factory layout and reduced product travel distance [21].

3. Methodology

This study uses AnyLogic software with Discrete-Event Simulation (DES) method to simulate, analyze and determine the optimization solution for furniture manufacturing process.

The research process was implemented in 5 steps (Figure 3).

Step 1. Study the theoretical basis.

Step 2. Survey and collect data from the production system

Step 3. Standardize input data

Step 4. Simulate the production process using AnyLogic software.

Step 5. Run the optimization model by changing the number of resources

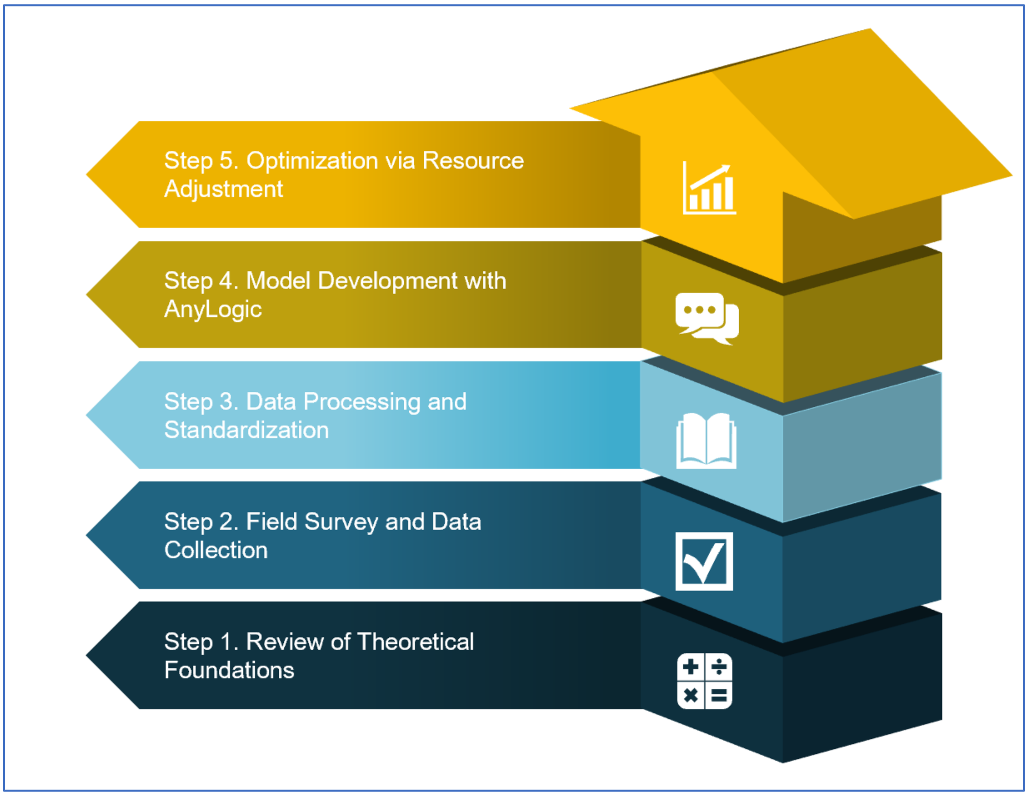

Figure 3. Research Methodology

4. Case study

4.1. Simulation Model

In this study, the simulated object is the production process of a table and chair set at a furniture manufacturing enterprise in Vietnam. This process includes many stages: cutting raw materials, processing details, sanding, painting and assembling the finished product (Figure 4).

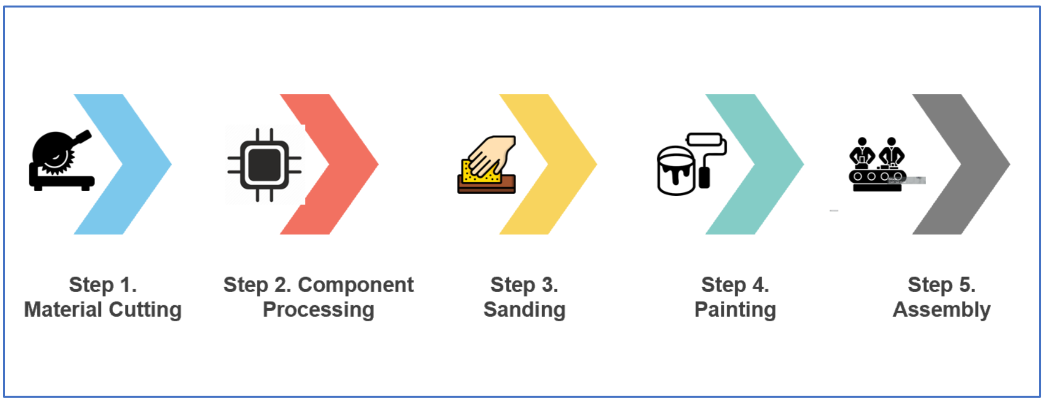

Figure 4. Production Process

The production process of the table and chair set includes 5 Steps:

Step 1. Material Cutting: wood is cut and sawed according to the technical design dimensions.

Step 2. Component Processing: includes drilling, milling, edge polishing and shaping by CNC machine

Step 3. Sanding: the goal is to smooth the surface.

Step 4. Painting: includes primer, color paint and clear paint to increase aesthetics and durability.

Step 5. Assembly: details are connected by accessories and complete the finished product.

Resources are allocated to each stage of the production process. In the cutting stage, resources include cutting machines and cutting workers. The processing and sanding stages use direct labor, each stage has workers doing tasks such as drilling, milling and surface smoothing. The painting stage uses an automatic paint booth. Finally, the assembly stage resources have highly skilled workers to ensure product quality. Details of the current resource numbers are described in Table 1.

Table 1. Resources

Production Process	Resources
Step 1. Material Cutting	- 3 cutting workers - 3 cutting machines
Step 2. Component Processing	- 9 processing workers
Step 3. Sanding	- 6 sanding workers
Step 4. Painting	- 2 paint booths

Production Process	Resources
Step 5. Assembly	- 2 assembly workers

The production time data of each stage was collected by direct measurement method to ensure the simulation process is accurate. The processing time of each stage was taken 50 times to ensure the representativeness and reliability of the data sample. Then, statistical tools were used to determine the type of data distribution. The detailed analysis results of the time and probability distribution of each stage are presented in Table 2.

Based on the steps in the manufacturing process, the study simulated the process flow using AnyLogic software. In this model, each production step is represented by simulation blocks. Each block not only describes the operational logic but also allows the integration of actual time and resource data collected. The detailed structure of the simulated process flow and functional blocks is shown in Table 3 and Figure 5.

Table 2. Processing Time

Production Process	Processing Time
Step 1. Material Cutting	uniform(25, 35 minutes per pcs
Step 2. Component Processing	triangular(88, 95, 105) minutes per pcs
Step 3. Sanding	triangular(54, 56, 60) minutes per pcs
Step 4. Painting	200 minutes per 1 Batch (10 pcs)

Production Process	Processing Time
Step 5. Assembly	uniform(90, 100) minutes per pcs

Table 3. Process Flowchart

Production Process	Blocks type	Blocks name
	Source	materialArrival
Step 1. Material Cutting	Queue	queue_MaterialCutting
	Seize	seize_CuttingResources
	Delay	delay_CuttingProcess
	Release	release_CuttingResources
Step 2. Component Processing	Service	service_ComponentProcessing
Step 3. Sanding	Service	service_Sanding
Step 4. Painting	Batch	batchForPainting
	Service	service_PaintingProcessBatch
	Unbatch	unbatchAfterPainting
Step 5. Assembly	Service	service_Assembly
	Sink	finishedProducts

After simulating the manufacturing process in both 2D and 3D using AnyLogic software, the study ran the simulation for 10,000 minutes to compare the simulation and actual production. The simulation shows the product flow and resource usage in each stage. The simulation results are detailed in Figure 5.

The simulation results show that the cutting machine utilization rate is 99%, the painting room utilization rate is 90%, the worker utilization rate of cutting, machining, sanding and assembling stages is 99%, 99% and 93% respectively. The average utilization rate of all resources is 95.1% and the total output is 885 products. The simulation results are similar to reality. Therefore, the model has been designed correctly and accurately.

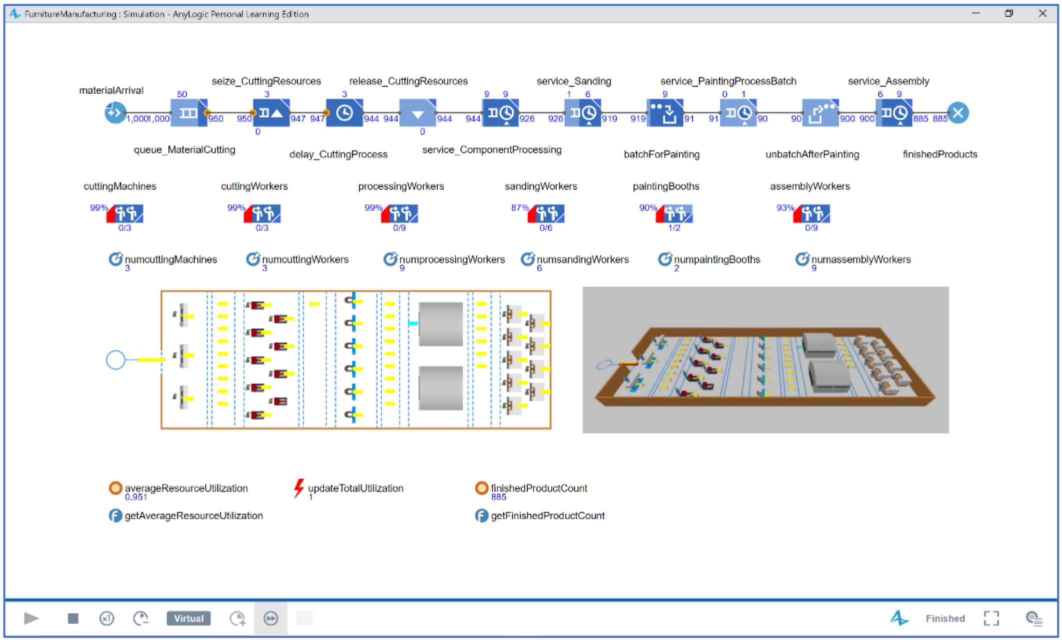

Figure 1. Results of the Current Simulation Model

The simulation results show that the production process has an imbalance of resources and bottlenecks at some stages. Therefore, the study proposes using AnyLogic simulation software to change the number of resources to find the most optimal resource solution.

4.2. Optimizing Resource Utilization

After running the simulation for 10,000 minutes, the resource utilization efficiency of each stage, as well as the average resource utilization level, was calculated. These results are an important foundation for identifying bottlenecks and improvements in the production process. Based on that, the study will focus on finding the optimal solution to improve the overall resource utilization efficiency.

The optimal model running properties are shown in Figure 6.

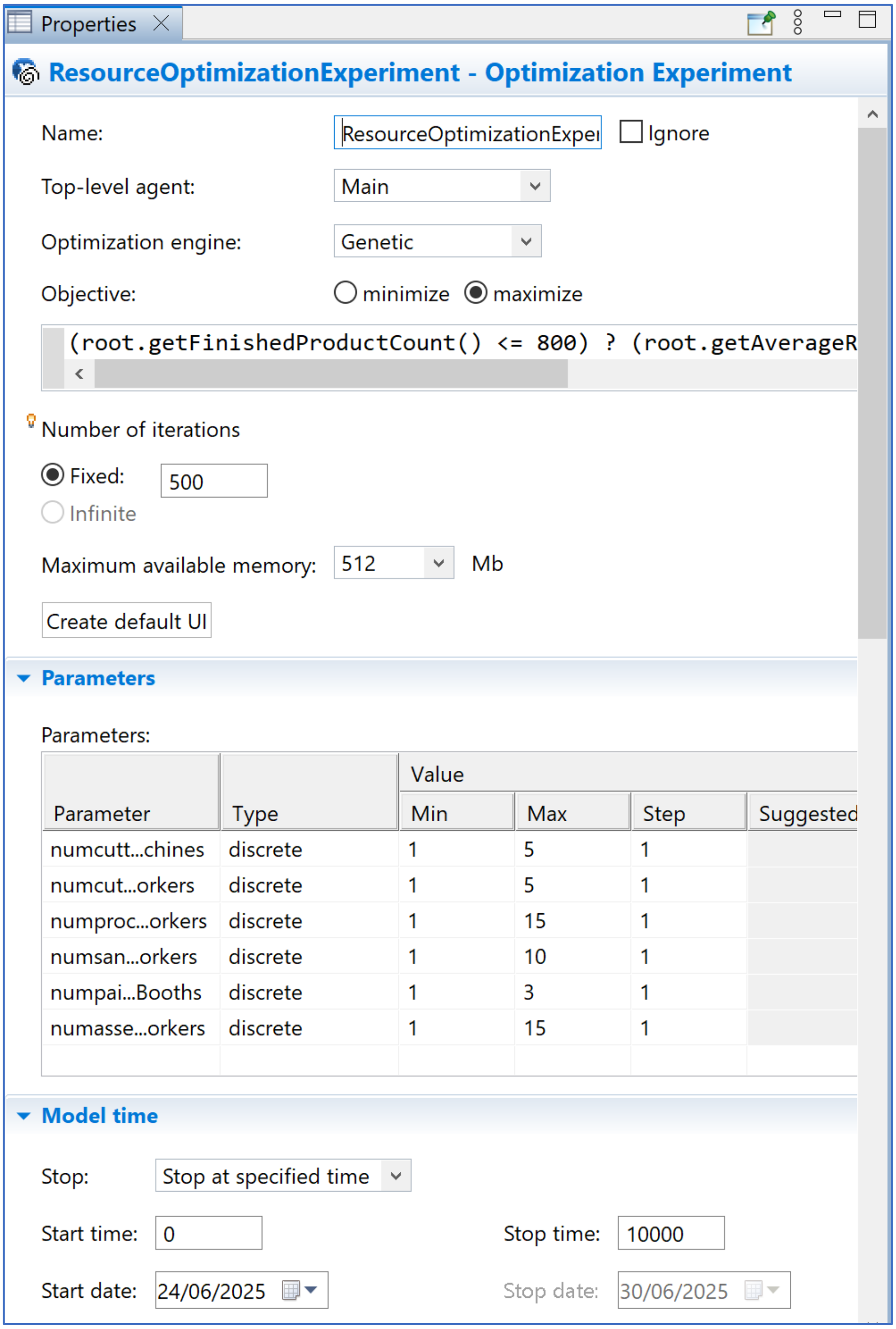

Figure 6. Optimization Properties

Objective: Maximize the efficiency of resources and within 10000 minutes, must complete at least 800 output products (quantity to complete the business order).

Number of iterations: 500 times.

Simulation run time: 10000 minutes.

Resource change: Step is 1 unit. The number of cutting machines and cutting workers changes from 1 to 5, the number of processing workers and assembly workers changes from 1 to 15, the number of sanding workers changes from 1 to 10 and the number of painting booths changes from 1 to 3.

After setting all the properties in the optimization model, the study ran this model. The results are shown in Figure 7.

The study ran the simulation 197 times, the highest efficiency was 96.7% corresponding to the following resource arrangement:

- Number of cutting workers: 4
- Number of cutting machines: 4
- Number of processing workers: 10
- Number of sanding workers: 6
- Number of painting booths: 2
- Number of assembly workers: 9

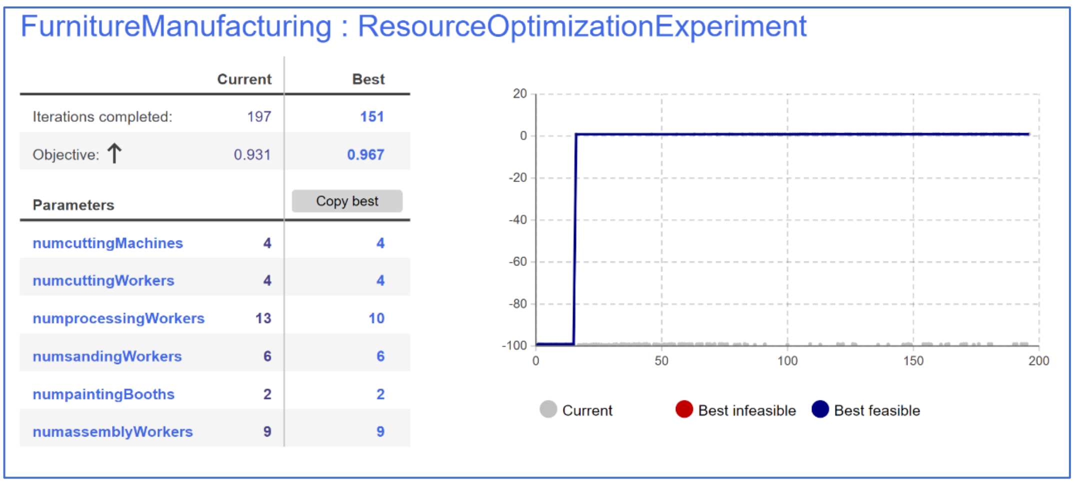

Figure 2. Results of the Optimized Simulation Model

The results from the optimization simulation model show that changing the number of resources at production stages will change the overall resource utilization efficiency. The optimization model helps to increase the resource utilization rate and reduce the waiting time between stages.

These results not only confirm the effectiveness of the optimization solution, but also provide an important practical basis for enterprises to make decisions to improve the production process.

After that, the enterprise changed resources to match the optimal model, and the result of resource utilization efficiency increased.

5.Conclusion and Recommendations

5.1. Conclusion

This study used AnyLogic software to simulate the production process in a furniture manufacturing enterprise in Vietnam. The simulation results showed that the current production process had bottlenecks and wasted resources. From there, the optimization solution was found by changing the number of resources at each stage. After running the model to optimization, the resource utilization rate increased from 95.1% to 96.7%. This result also demonstrates the effectiveness of applying simulation to support decision-making in a modern industrial context.

5.2. Recommendations

Enterprises should use simulation as a decision support tool in production management. AnyLogic software is a very good software for simulation in this case. In addition, enterprises can expand the scope of simulation to determine more factors such as costs, product quality and supply chain. It helps enterprises form a comprehensive decision support system, improve competitiveness and sustainable development in the context of Industry 4.0

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