

# APPLICATION OF TECNOMATIX IN SIMULATION AND OPTIMIZATION OF MANUFACTURING PROCESSES IN THE FACTORY

Hoang Lam<sup>1</sup>, Nguyen Huu Loc<sup>1</sup>, Nguyen Xuan Tung Lam<sup>1</sup>,  
Pham Le Bac<sup>1</sup>, Pham Van Sang<sup>1,\*</sup>

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## ABSTRACT

In this study, we examine the application of Tecnomatix Plant Simulation software in simulating and managing the production processes of businesses. Starting from an initial model of a production packaging assembly line, we utilize Tecnomatix software to calculate the efficient performance of each machine and workstation. The research also demonstrates the level of influence when adjusting the parameters of equipment and machinery, thereby providing suitable adjustment options to address production line issues and achieve higher output. As a result, we improve the factory model, alleviate bottlenecks in the production line, and enhance overall plant management. Specifically, we have increased the efficiency of the factory by 230% compared to before the adjustments.

**Keywords:** Enhance overall plant management; production line; factory management; Tecnomatix

<sup>1</sup>Hanoi University of Science and Technology, Vietnam

\*Email: sang.phamvan@hust.edu.vn

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## 1. INTRODUCTION

Currently, many factories are being built, leading to a high demand for managing production lines and optimizing factory operations. Modeling allows the detection and resolution of issues that arise in the initial stages of testing assembly systems [1] or production lines [2], resulting in significant cost and time savings [3]. This enables managers and engineers to make assumptions, calculations, and efficient analyses of production processes in a safe environment that doesn't affect actual production. If there's a need to change a production process, businesses can apply modifications to the digital model for testing before implementing them in reality. However, it's important to note that simulating production processes is merely a supportive tool and can't perfectly replicate real production. The use of production process simulation should be combined with quality control methods and safety assurances in actual production to achieve maximum effectiveness.

Tecnomatix Plant Simulation is primarily simulation software designed for logistics and production processes, a powerful analytical tool that's widely used in scientific research, mainly to create discrete event simulation models [4].

This simulation method facilitates modeling various elements within a production process, such as equipment, machinery, robots, or workers. Additionally, this method provides simulation results that support factory management and operational optimization.

Tecnomatix Plant Simulation also provides the capability to conduct statistical analyses on data. This encompasses exploring relationships between variables, determining correlations, applying regression techniques, fitting data, and performing ANOVA (Analysis of Variance), among others. Moreover, the software offers the flexibility to import data from external sources like Access, Oracle, Excel, SAP, and AutoCAD. An instrumental feature of the program lies in its integrated tool for crafting unique algorithms and scripts known as "Method." This is facilitated through the utilization of SimTalk, an in-built language with a syntax structure akin to Basic [5].

## 2. METHODS OF SIMULATION

To conduct the simulation of the manufacturing process in our factory, we have chosen Tecnomatix Plant Simulation software and the packaging and transportation line. Through simulation and modeling [6], we gather data such as product quantities, processing times, optimal production line operation time, and bottlenecks in the workflow. From these results, we analyze the encountered issues and propose various solutions.

### 2.1. Simulation Objects

#### 2.1.1. Worker

Tecnomatix provides a worker object to represent workers in the production process, simulating the activities and work of workers in a 3D factory. The software uses the functions `getRouteLength`, `goTo`, `goToPool`, etc. to define attributes and mobility of workers in 4-dimensional space. From there, calculate the speed and efficiency of work for each worker. In addition, workers' jobs are also defined

through service functions to interact with other components in the model such as machines, production lines, materials, etc. These interactions include receiving and sending materials, using tools and equipment, performing activities according to the production process: transporting materials, assembling products, checking quality...

The `getRouteLength` function has the form:

`<Path>.NameOfMethod(Target:path)`

Where: `<path>` is a name of part.

`NameOfMethod` is the name of function.

`getRouteLength` → length is a function that returns the length of the path returned from path to Target:path.

`goTo` is the function that sets the target object

`goToPool` → boolean is a function that sets the rest object

Target:path is the target object.

Eg: `Resources.CongNhan1.getRouteLength(NoiLamViec)`  
→ 10m

`Resources.CongNhan1.goTo(NoiLamViec)`

`Resources.CongNhan1.goToPool`

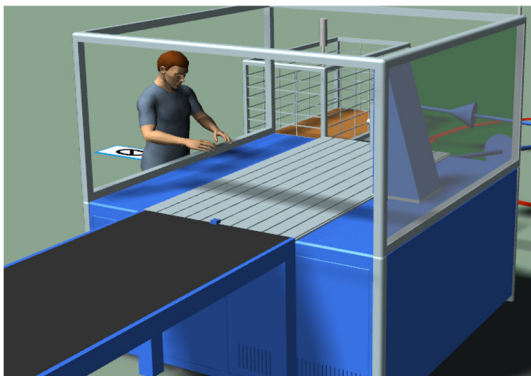


Fig. 1. Worker Model

### 2.1.2. Station

The station is provided by Tecnomatix as an object capable of handling the steps in a production process and can connect with other objects. The station templates available in Tecnomatix use the generic method of manufacturing process transition objects (Material Flow Objects) to get information from a part, then calculate the value, and then return value to the next connected parts in the manufacturing process.

There are different types of stations in Tecnomatix Plant Simulation, for example single processing station (SingleProc), parallel processing station (ParallelProc), assembly station (AssemblyStation), disassembly station (DisassemblyStation) and buffer (Buffer). Each type of station has unique characteristics and functions to suit different simulation scenarios.

In addition, One station can perform many different jobs depending on the product type and process requirements. All parameters such as: Processing time for each job step,

waiting time between job steps, maximum number of products that can be processed at one time can be customized to set up a station treatment equivalent to reality. From there, the software will calculate and then pass the values to the next part to process.

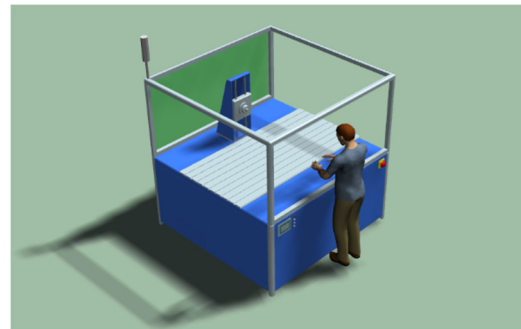


Fig. 2. Station Model

### 2.1.3. Robot Pick and Place

Pick and Place robots are industrial robot types designed for tasks such as manipulating and transporting objects (goods, crates, boxes, etc.) from one location to another. Tecnomatix provides functions like `setAnglesTable`, `setDestination`, and `setTimestable` to create robot motion in space over time. Additionally, attributes such as `BlockAngle`, `DefaultAngle`, `LoadingTime`, `MUConveyingDirection`, `Capacity`, etc., need to be specified for the robot. Subsequently, the software performs calculations to provide performance parameters and speed-related data for the robot. Integrating robots within the factory environment enhances the flexibility of transportation and manufacturing operations. The `setDestination` function has the form:

`<Path>.setDestination(DestinationObject:any[, WaitAtTarget:boolean])`

`<Path>.setDestination(DefaultPosition:void)`

Where: `<path>` is the part name to be adjusted.

`setDestination` is the name of the function that adjusts the target point of the robot.

`WaitAtTarget` is the returned data type of the function.

`<boolean>` is the returned value of the function.

For example:

`# set the destination of 1 robot`

`if @.destination = SP3`

`PickAndPlace.setDestination(@.destination, false)`

`else`

`PickAndPlace.setDestination(@.destination, true)`

`end`

`print PickAndPlace.getDestination`

The `setDestination` function is used to set the destination of the picking and moving robot. If the value of the `@.destination` variable is `SP3`, the robot will move to `SP3`'s location, but not wait there. Conversely, if the value of

variable@.destination is different from SP3, the robot will move to the specified location and wait there until the next command is received. After calling the setDestination function, the code uses the getDestination function of the PickAndPlace object to print the robot's current destination, the point where the robot was previously set by the setDestination function.

The setup of the functions setAnglesTable and setTimestable is similar to the function setDestination.

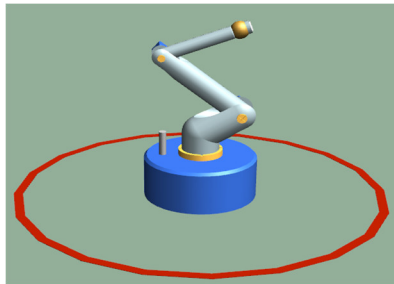


Fig. 3. Model Pick and Place robot

**2.1.4. Conveyor**

Conveyor belts are introduced to simulate the material handling system during production. Tecnomatix provides functions to define conveyor speed, input, and output. The conveyor moves at a specified speed and can contain flow objects such as goods, production materials, etc. These objects will be moved to different locations on the conveyor using the AttributesOfTheConveyor function. This function is set to adjust the travel direction, speed, acceleration and other parameters related to the conveyor. Alternatively the conveyor can be set to operate continuously or only when an object is placed on it.

The AttributesOfTheConveyor function comprises functions such as Acceleration, Accumulating, AutomaticStop, Capacity, MUDistanceType, MUDistance, Speed,...

Among these functions, the format of each function is as follows:

<Path>.NameOfAttribute:<boolean>

Where: <path> is the name of the adjusted component.

NameOfAttribute is the user-adjusted function or attribute name.

<boolean> is the returned value of the function.

For example: BangTai1.AutomaticStop := true  
BangTai1.Acceleration := 2

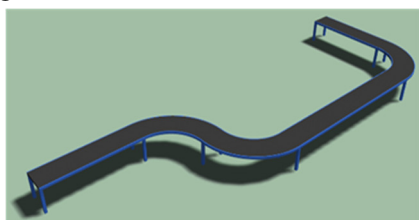


Fig. 4. Conveyor model

**2.2. Overview of the model and the initial working process**

In this model, elements such as Products, Boxes, and Pallets are continuously supplied throughout a day. The initial source of Products depends on the area where the products are stacked.

Initially, a worker carries Products from the source to the first workstation, where they are packaged. After packaging, they are then transported via a conveyor to the Product Inspection Station. At the waiting station, the recently packaged Products undergo inspection before a robotic arm picks and places them in the area designated for completed products stacking.

In a separate branch, we have designed another robotic arm to directly pick Cardboard sheet from the supply source and drops it on the conveyor belt. Then the sheets are transported by conveyor belt to the Box Preparation Station. At this station, it symbolizes the assembly of the box and applying adhesive tape to the bottom. The next step involves arranging the Products into the Box. Factory workers will pick Products from the product stacking area and place them into the Box.

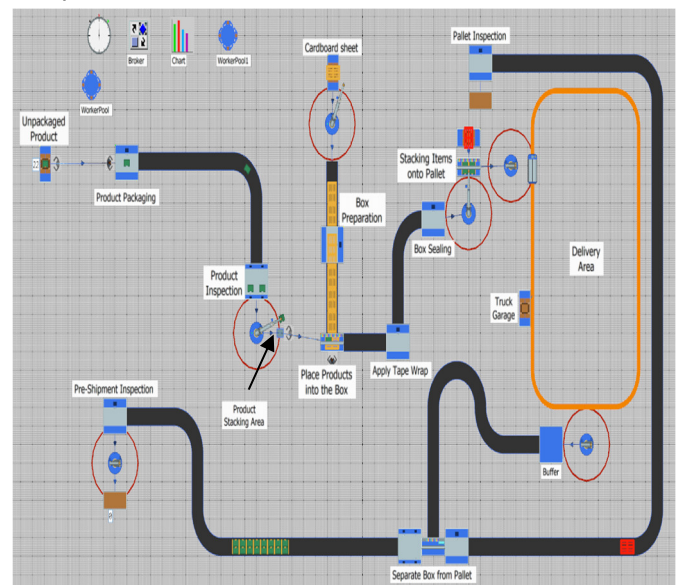


Fig. 5. Model of packaging and transportation line

After the Products are placed into the Box, it will go through the Boxing and Adhesive steps one by one before being picked up and placed on the Pallet. Pallets will be automatically placed on the table and waiting for the robot to pick up the goods. When there are enough goods on the pallet, the next arm will pick them all up and load them onto the cart.

The truck is set to travel from the loading area to the unloading area. The next robotic arm picks the items from the truck and places them into a storage area. The items then proceed to the disassembly section. The Product Boxes and Pallets are separated. Product Boxes return to storage, while Pallets are processed and returned to the initial source.

Table 1. Processing time of each machine in the production line

Station	Station	Time Processing (seconds)
root.DongGoi	Product Packaging	15
root.KtraSanPham1	Product Inspection	10
root.ChuanBiHop	Box Preparation	15
root.XepSanPhamvaoHop	Placing Products into the Box	5
root.DongHop	Box Sealing	2
root.BocHop	Applying Tape Wrap	10
root.RaHang	Separate Box from Pallet	50
root.KiemTra	Pre-Shipment Inspection	10
root.KiemTraPallet	Pallet Inspection	10
root.XepHangLenPallet	Stacking Items onto Pallet	30

**3. RESULTS AND DISCUSSION**

**3.1. Result**

After performing the operational setup procedures, the simulation obtained after 24 hours of this production the output was 536 boxes of products. The performance of individual workstations in the encapsulation process is shown in Fig. 6.

Table 2. Performance statistics at stations for a day

Station	Working (%)	Waiting(%)	Blocked(%)
root.DongGoi	37.49	62.51	0.00
root.ChuanBiHop	9.46	0.58	89.96
root.RaHang	7.75	92.25	0.00
root.BocHop	6.24	90.23	3.53
root.KtraSanPham1	6.24	82.08	11.68
root.KiemTra	6.20	76.12	17.68
root.XepHangLenPallet	4.65	91.02	4.33
root.XepSanPhamvaoHop	3.12	96.88	0.00
root.KiemTraPallet	1.55	98.45	0.00
root.DongHop	1.25	98.75	0.00

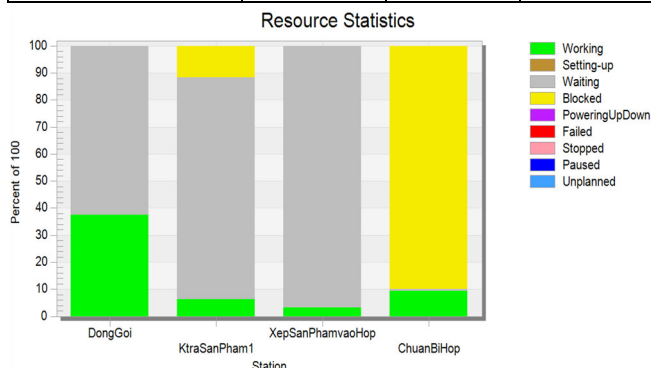


Fig. 6. Performance statistics in the Product and Box areas

The results in Fig. 6 illustrate the real-world working efficiency in each area. For the Product Packaging process, the operational efficiency is around 38%. The efficiency of

the Box Preparation station is low, approximately 10%, with a congestion rate of up to 90%. These outcomes indicate suboptimal working efficiency in each working area, along with significant waiting times and congestion within the process.

The congestion that occurs on the Box Preparation station is due to too many Boxes being processed but the Placing Products into the Box station cannot handle it in time. The explanation for this issue lies in the disparity between the quantity of supplied Boxes and Products. In this scenario, the initial supply of Products for processing is inadequate, or the supply of Boxes is overly rapid. To address this concern, we propose two solutions:

- Adjusting the feed speed of the box
- Increase the input quantity of Products.

**3.2. Solution**

**3.2.1. Adjusting the feed speed of the box**

After increasing the picking time of the robot arm in one cycle in the picking Cardboard stage from 6 seconds to 14 seconds, thereby reducing the input speed of the Box, the output is 535 units produced and statistical of the Prepare Box station (Fig. 7).

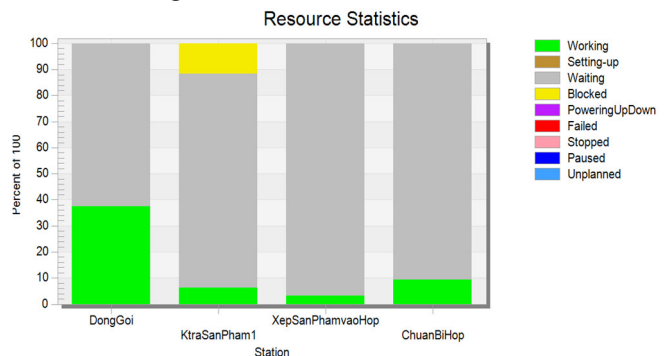


Fig. 7. Performance of stations with a robot arm cycle of 14 seconds

It is easy to see that the blocking time has expired. However, the productivity of the day did not change much compared to the original. For this approach, the bottleneck has been resolved, but the output quantity will not be improved.

**3.2.2. Increase the input quantity of Products**

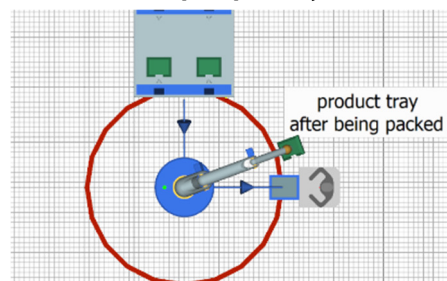


Fig. 8. Product tray model

Initially, we set the tray size to accommodate 4 Products. To increase the input quantity of Products, the product supply method will transition to continuous supply,

independent of the Product Stacking Area 1. This is achieved with an unchanging tray size, which applies to both cases where the robot arm operates on cycles of 6 seconds and 14 seconds in the aforementioned solution.

The outcome of a 14-second operational cycle of the robotic arm yields a total of 536 units produced. Fig. 9 illustrates the performance of various machines under this scenario. While the bottleneck at the Box Preparation Station has been resolved, a new bottleneck has emerged in the Packaging area.

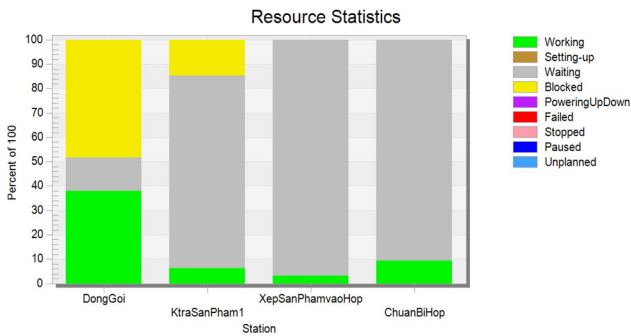


Fig. 9. Performance of stations in the case of a robot arm cycle of 14 seconds

In the scenario where the robotic arm operates for 6 seconds per cycle, the output result is 612 units. In this case, we observe an increase in the quantity of products produced. However, a bottleneck issue has arisen in the Packaging area once again, despite the higher production rate, indicating congestion at the Preparation Station.

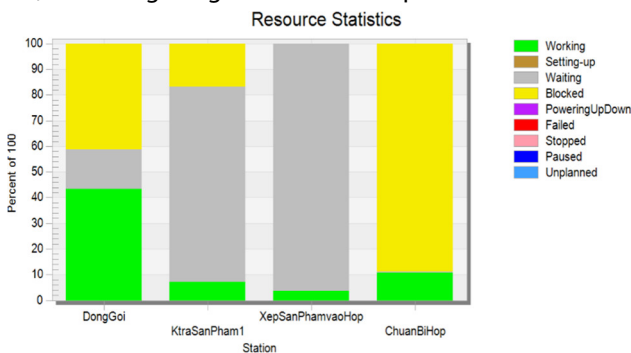


Fig. 10. Performance of stations in the case of robot arm cycle of 6 seconds

Based on the above two results, the solution to increase input output is suitable for the purpose of increasing the number of output products. However, the time of congestion in areas is still large. So to help the production line both increase output and solve bottlenecks, we're going to make some improvements at the initial product handling stage.

**3.2.3. Change and improve product handling area**

The supply source continues to directly feed the packaging machine. Following the packaging process, the products are evenly distributed onto two conveyor belts using the FlowControl control tool. For each conveyor belt, the products are conveyed to separate Inspection Stations. With this approach, the product flow into the packaging process increases, while simultaneously, the workload on

the robotic arm remains manageable without being overwhelmed.

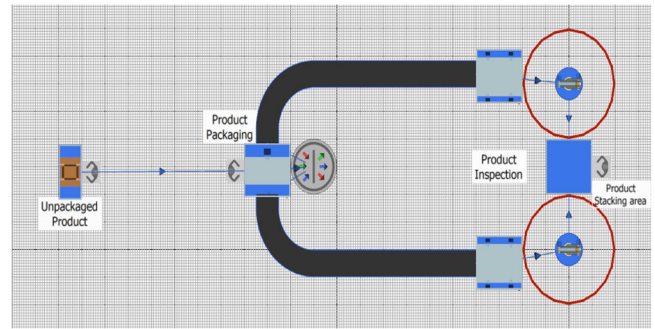


Fig. 11. The conveyor belts transport the products to the Product Inspection Station

Due to the increased product input, the product stacking area has also undergone improvements. A buffer with a capacity of 50 products has been introduced to replace the 2x2x1 product tray. This modification enables workers to continuously move products to the subsequent stage without waiting for the products on the tray.

The Product Inspection Station has also undergone reconfiguration. The robotic arm at this position can now grasp products from the station without the need to wait for a full quantity, unlike the initial setup. The product inspection process will commence immediately upon the arrival of products.

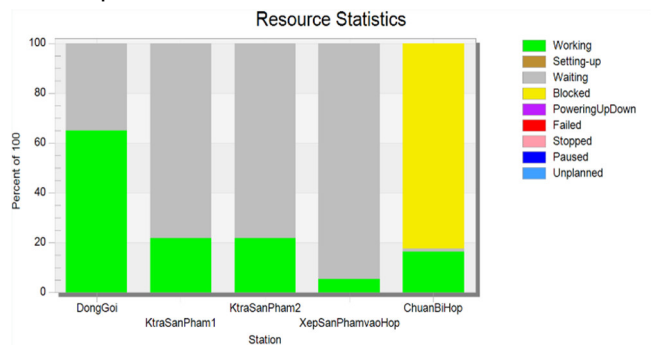


Fig. 12. Performance at the stations after applying the changes

After making the adjustments and simulating for a day, the achieved outcome is 927 units. The increase in output is notable, though not excessively substantial. This can be attributed to the fact that the product supply source has yet to be fully aligned with the quantity of boxes being provided, leading to a constrained increase in production.

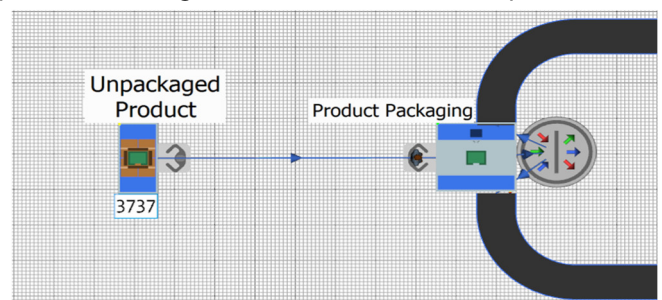


Fig. 13. The stage of putting products into packaging with 1 worker

The product supply source into the production line is currently set at 3737 units. When the products are supplied, a worker is designated to manually transport the products from the source to the Packaging Station at a speed of 1.5m/s.

Due to the increased demand for the product supply, it is necessary to augment the workforce at this stage. Since altering the transportation speed is not a readily changeable factor in reality, we will address this by increasing the number of workers to 2 at this particular stage.

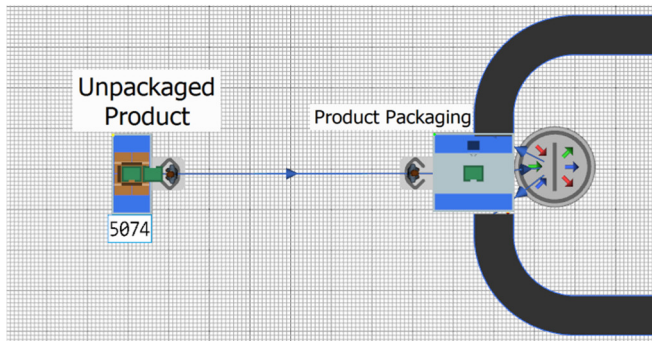


Fig. 14. The stage of putting products into packaging with 2 workers

The input quantity of products has been substantially increased. At this point, the output quantity stands at 1250 units, which is a 34% increase compared to the scenario with only one worker at this area. The chart indicates the absence of any bottlenecks in the Box and Product areas.

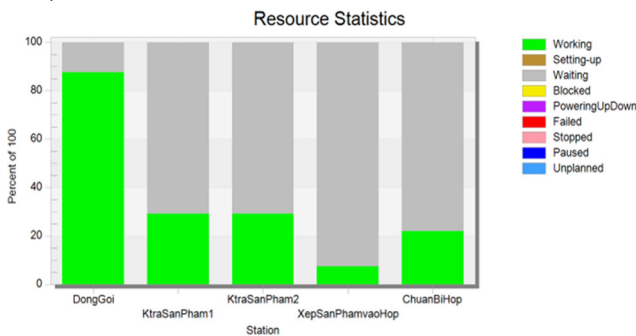


Fig. 15. Performance at stations after applying improvements

Table 3. Performance statistics at stations after improvement

Station	Working (%)	Waiting (%)	Blocked(%)
root.DongGoi	88.07	11.93	0.00
root.KtraSanPham1	29.35	70.65	0.00
root.KtraSanPham2	29.34	70.66	0.00
root.ChuanBiHop	21.82	78.18	0.00
root.RaHang	18.11	81.89	0.00
root.BocHop	14.54	77.23	8.24
root.KiemTra	14.48	44.28	41.24
root.XepHangLenPallet	10.90	78.97	10.12
root.XepSanPhamvaoHop	7.27	92.73	0.00
root.KiemTraPallet	3.62	96.38	0.00
root.DongHop	2.91	97.09	0.00

The percentage of "Blocked" represents the bottleneck in the process, which is now minimal. The Final Inspection Station occurs this situation because the amount of product to check each time is 4 while the machine only allows to test once per product. To address this problem, a waiting station can be placed before this inspection station, although the product quantity won't change. The overall impact on the final result is predominantly influenced by the processing of the Product and Box areas.

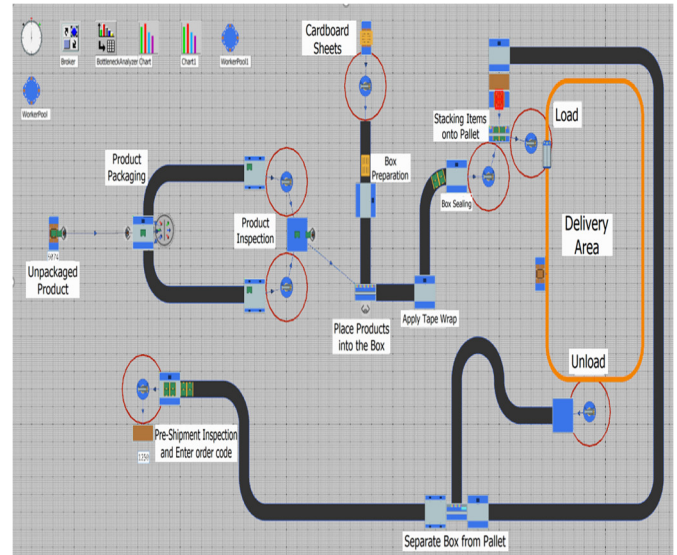


Fig. 16. Packaging and shipping line model after applying improvements

#### 4. CONCLUSIONS

In this paper, a research study was conducted to address the challenges faced in the production line using simulation-based methods. Simulations of each improvement were analyzed and optimized to enhance the output quantity. The results demonstrated a nearly 2.33-fold increase in the output compared to the initial state. Moreover, issues encountered in the production line, such as waiting times and equipment bottlenecks, were also resolved. Additionally, the research highlighted the extent of the impact when adjusting parameters of devices and machinery, thereby providing appropriate adjustment strategies to tackle production line issues and achieve higher yields.

The numerical simulation model in this study found applications in manufacturing processes and logistics, aiming to boost work efficiency and optimize economic problems. The outcomes of this research can be applied to enhance the efficiency of production lines across various industries. Furthermore, the numerical simulation model can also be employed to optimize production processes. By simulating production lines and processes, managers can identify latent issues and propose solutions to enhance performance.

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