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Modelling an Assembly Line Using Tecnomatix Plant Simulation Software

Nur Asyiqah Afizul[1], Mohamad Ali Selimin[1]*, N.A. Pagan[2], Ng Khang Yinn[2]

[1] *Department of Production and Operations Management, Faculty of Technology Management and Business Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA*

[2] *Evergreen Fibreboard Berhad, PLO 22, Parit Raja Industrial Estate, Batu Pahat, Johor, 86400, MALAYSIA*

*Corresponding Author: aliselimin@uthm.edu.my
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Abstract

Industries operate under unyielding pressure to meet the escalating demands of customer orders. However, various configurations of production lines often lead to inefficiencies in productivity. Addressing this challenge, simulation techniques offer preliminary insights, crucially aiding in the early detection of potential bottlenecks. This study focuses on employing Tecnomatix plant simulation software to identify bottlenecks within existing furniture assembly lines. The findings of this investigation highlight a bottleneck in the taping process, significantly impacting line balancing. Through simulation, the study observed a substantial increase in throughput, from 358 to 1027 units, after some changes were made to the identified bottleneck. Insights gained from Tecnomatix plant simulation facilitate evidence-based decision-making, empowering the company to optimize production capacity effectively. By addressing identified bottlenecks, the company can enhance its ability to meet customer demands efficiently. This underscores the critical role of simulation tools in streamlining production processes and maximizing operational effectiveness. Ultimately, the findings highlight the importance of continually refining and adapting manufacturing operations to remain competitive in today's demanding market landscape.

1. Introduction

In today's rapidly evolving manufacturing landscape, the quest for operational excellence has become increasingly paramount for industries across the spectrum, including furniture manufacturing. With escalating customer demands, fierce competition, and evolving market dynamics, the traditional manual approaches to streamline production capacity are proving inadequate. As such, there's a growing recognition of the need for manufacturing industries to embrace advanced technological solutions, particularly simulation software, to drive efficiency, balance workloads, and optimize resources and manpower (Vidrova *et al.*, 2021).

Manual methods of production management often fall short in effectively addressing the complexities inherent in modern manufacturing operations and time consuming (Maria, 1997). Balancing workloads across different processes and optimizing the utilization of resources and manpower require meticulous planning and execution, tasks that are prone to human error and inefficiencies. Moreover, the dynamic nature of production environments necessitates real-time adaptability, a feat that manual approaches struggle to achieve efficiently.

Simulation software offers a compelling alternative, providing a sophisticated platform for modeling and analyzing manufacturing processes in a virtual environment (Marasova *et al.*, 2020). By replicating real-world scenarios and dynamics, simulation software enables manufacturers to gain valuable insights into their operations, identify potential bottlenecks, and evaluate the impact of proposed changes or improvements before implementing them in the actual production environment (Mourtzis, 2020). In essence, the adoption of simulation software represents a paradigm shift in manufacturing management, offering a transformative solution to the challenges of balancing workloads, optimizing resources, and enhancing productivity. By leveraging the power of simulation, manufacturing industries, including furniture manufacturing, can unlock new levels of operational efficiency, agility, and competitiveness in today's dynamic business environment.

In the context of furniture manufacturing, where intricate assembly processes and tight production schedules are commonplace, the adoption of simulation software holds immense promise. By simulating production workflows, manufacturers can optimize production layouts, fine-tune resource allocation, and streamline manufacturing processes to enhance overall efficiency and productivity. Furthermore, simulation software facilitates scenario analysis, allowing manufacturers to explore various "what-if" scenarios and assess their implications on production outcomes. This proactive approach empowers manufacturers to make informed decisions, mitigate risks, and seize opportunities for process optimization and improvement in very short time compare to traditional/manual approach. Achieving optimal production efficiency hinges on effectively balancing the assembly line. Line balancing involves distributing work elements evenly across workstations to minimize idle time and maximize throughput (Islam *et al.*, 2019). However, managing the diverse range of furniture models poses challenges due to unique assembly processes, leading to workload disparities and bottlenecks (Abdous *et al.*, 2023). Fluctuating consumer preferences and market demands further complicate line balancing in furniture manufacturing (Bambura *et al.*, 2020). Frequent adjustments to production schedules disrupt workflow and increase setup time and costs, impacting overall productivity.

Small batch sizes exacerbate inefficiencies in line balancing. Furniture manufacturers, geared for mass production, struggle to adapt to small orders, leading to suboptimal resource utilization. Traditional manual line balancing methods lack flexibility and agility to adapt to modern production environments (Trebuna *et al.*, 2019). Human-dependent approaches may not yield optimal results, especially with intricate production processes and fluctuating demand.

To address these challenges, furniture manufacturers must adopt advanced technologies like simulation software (Blaga *et al.*, 2017). Tecnomatix Plant Simulation offers a virtual environment to model and analyze production workflows, identifying bottlenecks and optimizing resource allocation. By leveraging simulation software, furniture manufacturers gain valuable insights to improve efficiency and productivity (Urban & Rogowska, 2018). Simulation-driven analysis enables proactive identification of production challenges and optimization opportunities. Line balancing is crucial for furniture manufacturers facing diverse product models, fluctuating demands, and small batch sizes. Embracing simulation software allows manufacturers to overcome these challenges and enhance operational efficiency (Afazov, 2013). By optimizing line balancing, furniture manufacturers can reduce costs, improve productivity, and remain competitive in the dynamic market landscape.

Therefore, this study aims to assess a company's furniture assembly line efficiency, pinpointing bottleneck processes, and proposing improvement solutions. Using Tecnomatix plant simulation, it provides actionable insights into current production dynamics, identifying areas for enhancement and optimizing furniture assembly processes. Ultimately, the research aims to equip the company with tools to navigate challenges, fostering continuous improvement in efficiency and productivity.

2. Methodology

2.1 Data Collection

In this study, data collection involved utilizing interview and observation techniques primarily to gather pertinent information. Qualitative research methods, namely interviews and observations, proved valuable for obtaining detailed and subjective data. To ensure clarity, a predetermined set of essential questions was formulated in advance of the interview session.

Before observing the assembly line, an interview session was conducted with the production line manager, who was asked several questions to gain insights into various aspects of the production process. These questions included inquiring about the current furniture production process overview, key performance metrics for efficiency measurement, methods for identifying and addressing bottlenecks, encountered challenges in achieving optimal efficiency, available production data, suspected bottleneck areas, past analyses or studies on bottleneck identification and resolution, factors or constraints affecting production, and resource allocation and workflow determination methods.

Subsequently, the observation approach offered a comprehensive understanding of the organization's production process. By directly observing the assembly line, the researcher obtained valuable insights, enhancing comprehension and minimizing the likelihood of inaccuracies in information collection. Additionally, a time study was conducted to gather data crucial for simulation purposes especially to obtained the standard time for each process involved in assembly process as well as number of workers for each station.

2.2 Data Analysis

Data analysis entails examining information gathered from various sources using specific methods and techniques. It involves systematically collecting, recording, analyzing, and documenting relevant data to address research objectives or answer specific research questions, ensuring the accuracy, reliability, and validity of the collected information. Subsequently, data obtained from interviews and observations were utilized to simulate the production line using the Tecnomatix Plant Simulation application. Tecnomatix Plant Simulation is a software tool that offers a comprehensive platform for modeling, analyzing, optimizing, and validating proposed solutions for existing production system issues. The flow of using Tecnomatix Plant Simulation typically involves several key steps, as illustrated in Fig. 1. Based on the analysis of the current assembly process, this study proposes a solution to the identified bottleneck. This proposed solution will be validated using Tecnomatix plant simulation to ensure its efficacy in overcoming the bottleneck of the existing process by comparing the productivity of both before and after changes implemented.

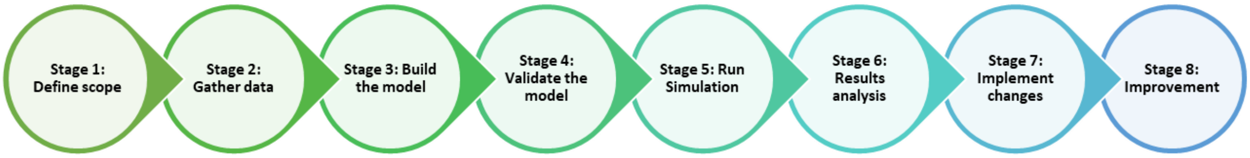

Fig. 1 *Steps for Tecnomatix plant simulation*

3. Results and Discussion

3.1 Interview and Assembly Line Observation (Stage 1)

In this study, the researcher interviewed two significant individuals: the HR Manager and the Plant Operations Manager. The goal was to look into the process and get insight into the assembly line operations. The interviews offered details regarding the company's layout, workers, and standard operating procedures (SOP). The researcher also observed the current status of the furniture assembly process flow, paying attention on the RS 106100QPWWN shoe rack model. The observation revealed the existence of ten workstations used in the assembling process.

3.2 Time Study (Stage 2)

During the time study, the durations for 10 stations were documented over 5 cycles, with each cycle corresponding to 5 shoe rack units. Based on the recorded times, the standard time was computed, as illustrated in Fig. 2. Based on the observation, by referring to the Westinghouse System of Rating Table, the performance rating of workers done by the Production Line Manager are fair skill (-0.05 E_1), average effort (0.00 D), average conditions (0.00 D), and average consistency (0.00 D). The calculation of performance rating (PR) as presented in Equation 1, where the PR for this study is 0.95. Meanwhile, the fatigue allowance is 15%. Analysis was conducted on this data, leading to several conclusions. The prolonged completion times for certain operations were found to have valid explanations. The primary focus of this study centers on manual labor, waiting times, and bottlenecks that arise during specific procedures. The researcher inferred from the data that a significant portion of the process relies on manual labor. Furthermore, manual processes were observed to require more time compared to the utilization of automated equipment.

$$\text{Performance rating (PR)} = 1 + \text{sum of ratings} \quad (1)$$

3.3 Bottleneck and Efficiency of Current Assembly Line (Stage 3 to Stage 6)

Table 1 provides a clear overview indicating that the taping operation (process 9) has the lengthiest operating cycle, averaging seconds. Among all operations involved, the taping process consumes the most time, with a duration of 61.8 seconds within the workflow. Following closely, the labelling procedure ranks second with a cycle time of 56.4 seconds, while putting board 3 ranks third with 34.2 seconds. This distribution underscores the diverse time requirements across operations. It can be inferred that potential bottlenecks may arise at procedures with the longest operating time, notably the taping process, warranting attention. Optimizing the taping operation, alongside other procedures, is crucial for enhancing production efficiency, in line with the objective of maximizing output and streamlining workflow. Fig. 3 shows the simulation model for the existing plant layout for shoe rack assembly line.

TIME STUDY WORKSHHET													
No.	ELEMENT DESCRIPTION		0		READINGS			Total/				1.15	
			1	2	3	4	5	CYCLE	AVG	PR	NT	ALLW	ST
1	Placing box	R	0.02	4.05	8.07	12.17	16.3						
		A	2	2	3	2	3	12	2.4	0.95	2.28	15%	2.62
2	Putting board 1	R	0.22	4.25	8.29	12.4	16.49						
		A	20	20	22	23	19	104	20.8	0.95	19.76	15%	22.72
3	Putting board 2	R	0.28	4.30	8.36	12.48	16.56						
		A	6	5	7	8	7	33	6.6	0.95	6.27	15%	7.21
4	MDF Hammer	R	0.43	4.47	8.52	13.04	17.13						
		A	15	17	16	16	17	81	16.2	0.95	15.39	15%	17.70
5	Polystrene 1	R	0.55	5.02	9.03	13.17	17.25						
		A	12	15	11	13	12	63	12.6	0.95	11.97	15%	13.77
6	Putting board 3	R	1.31	5.35	9.38	13.51	17.58						
		A	36	33	35	34	33	171	34.2	0.95	32.49	15%	37.36
7	Putting board 4	R	1.55	5.59	10.03	14.14	18.2						
		A	24	24	25	23	22	118	23.6	0.95	22.42	15%	25.78
8	Polystrene 2	R	2.08	6.11	10.14	14.26	18.33						
		A	13	12	11	12	13	61	12.2	0.95	11.59	15%	13.33
9	Taping	R	3.08	7.09	11.17	15.29	19.38						
		A	60	58	63	63	65	309	61.8	0.95	58.71	15%	67.52
10	Labeling	R	4.03	8.04	12.15	16.27	20.34						
		A	55	55	58	58	56	282	56.4	0.95	53.58	15%	61.62
													269.63

Fig. 2 *Time study sheet analysis*

Table 1 *Average cycle time and standard time of assembly line*

Station	Process	Cycle time (s)	Standard time (s)
1	Placing box	2.4	2.62
2	Putting board 1	20.8	22.72
3	Putting board 2	6.6	7.21
4	MDF hammer	16.2	17.70
5	Polystyrene 1	12.6	13.77
6	Putting board 3	34.2	37.36
7	Putting board 4	23.6	25.78
8	Polystyrene 2	12.2	13.33
9	Taping	61.8	67.52
10	Labelling	56.4	61.62

3.4 Potential Solution (Stage 7)

Addressing such challenges is critical for eliminating bottlenecks, increasing production output, and maintaining a competitive advantage in the continually changing furniture industry. According to prior studies, various viable ways exist to reduce or eliminate the bottleneck. Few alternatives were available for the assembly line of shoe rack manufacture, to solve the bottleneck that had been identified. The following solutions were chosen to create an alternative arrangement for the shoe rack assembly line:

i. Reassess the required number of workstations and manpower
ii. Implementing Theory of Constraints (ToC)
iii. Technology advancement

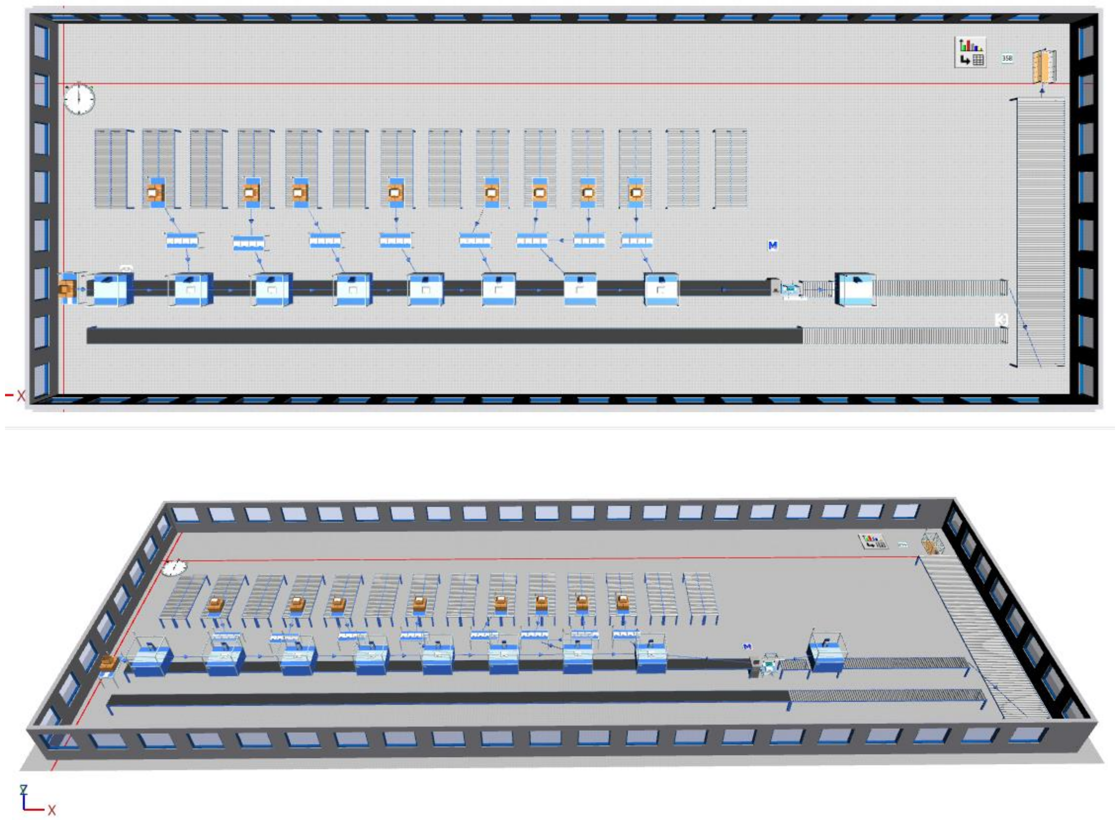

Fig. 3 *Current layout of shoe rack assembly line using Tecnomatix plant simulation*

Examine the taping process for potential areas for improvement. This might mean lowering cycle time with technology, optimising equipment performance, or simplifying manufacturing procedures. Furthermore, consider making investments in automation or cutting-edge technology to boost the tape process's capacity and efficiency. Finally, ensure that all other activities, particularly those preceding the taping procedure, are synchronized to avoid overloading the bottleneck. By using ToC, the identified bottleneck in the taping process may be made more efficient. This will result in reduced cycle times, increased throughput, and greater alignment with production goals.

On the other hand, the data presented in Table 1 clearly show that some processes can be consolidated into a single entity by rearranging the process layout. In particular, steps 2, 3, and 4 can be combined. The same goes for steps 6 and 7. Furthermore, manual task-based activities such as tape and labelling need greater processing time. Changes can be made to decrease and eliminate waste, hence improving the efficiency and effectiveness of the furniture production process flow. This includes eliminating waste related to waiting and moving to improve overall production efficiency.

Besides that, a new process flow can be established to enhance overall process effectiveness and increase production by integrating existing processes to simplify and improve the process flow. Several processes, such as putting in board 1, board 2, and the MDF hammer, can be merged into one as these processes are done manually by workers. Furthermore, the workstations, such as putting boards 3 and 4, can be joined. This may result in enhancements to the production process flow, seven workstations are now involved in the assembly of the shoe rack. Table 2 offers information about the proposed new manufacturing process flow.

Another approach that may be adopted is to reassign the operators on the shoe rack assembly line. This approach may increase the overall efficiency of the operation while also completely utilizing the operators. Optimizing the number of workers may also help to improve process efficiency and labour costs. Based on observations made on the assembly line, it was revealed that a substantial percentage of manufacturing processes rely on manual labour, resulting in lengthier production times. Using robotic technology can increase process efficiency while reducing labour hours and the number of human workers necessary. According to the data, some workstations, in particular, might benefit from the installation of robotics to improve overall production efficiency.

Table 2 *Proposed new manufacturing flow of shoe rack assembly line*

Station	Process
1	Placing box
2	Putting board 1
	Putting board 2
	MDF hammer
3	Polystyrene 1
4	Putting board 3
	Putting board 4
5	Polystyrene 2
6	Taping
7	Labelling

3.5 Implementation of Potential Solution for Improvement (Stage 8 – Stage 9)

First, referring to the suggested solution in Table 2, reassigning operators inside the shoe rack assembly line will increase overall process efficiency. The simulation findings suggest that reallocating operators to specific workstations can save time, balance the workload, and enhance process efficiency. Then, reassign the number of operators to respective workstations helps to improve process efficacy. A new process flow has been devised, and operators have been relocated. A new automated equipment was also installed to enhance process efficiency. Table 3 shows the results of relocating operators and installing an automated equipment. The comparison between total station and number of operators needed between existing and improved operators' allocation is tabulated in Table 4.

Table 3 *Proposed new allocation of operators*

Station	Process	Number of operators	Processing time (s)
1	Placing box	-	3
2	Putting board 1, Putting board 2, & MDF hammer	-	3367
3	Polystyrene 1	1	828
4	Putting board 3& board 4	1	826
5	Polystyrene 2	1	825
6	Taping	-	824
7	Labelling	-	823

Table 4 *Comparison between current and improve operators' allocation*

Current		Process	Improved	
No. of operator	Station		Station	No. of operator
1	1	Placing box	1	Machine
2	2	Putting board 1	2	Machine
2	3	Putting board 2		
1	4	MDF hammer		
1	5	Polystyrene 1	3	1
2	6	Putting board 3	4	1
1	7	Putting board 4		
1	8	Polystyrene 2	5	1
4	9	Taping	6	Machine
1	10	Labelling	7	1

Meanwhile, Fig. 4 displays the proposed new process distribution of shoe rack assembly line using Tecnomatix plant simulation software. The simulation study successfully demonstrates the contrasts between the proposed new process flow and the existing one. Surprisingly, production output rises dramatically from 358 to 1027 units (Fig. 5). Furthermore, the overall length for both instances remains constant at three hours, suggesting a significant increase in productivity and efficiency as a result of the recommended process change. The solution does more than fix the existing bottleneck; it also saves the company money in various ways. This is consistent with the basic goal of simulation, which is to minimize costs while maximizing productivity efficiency.

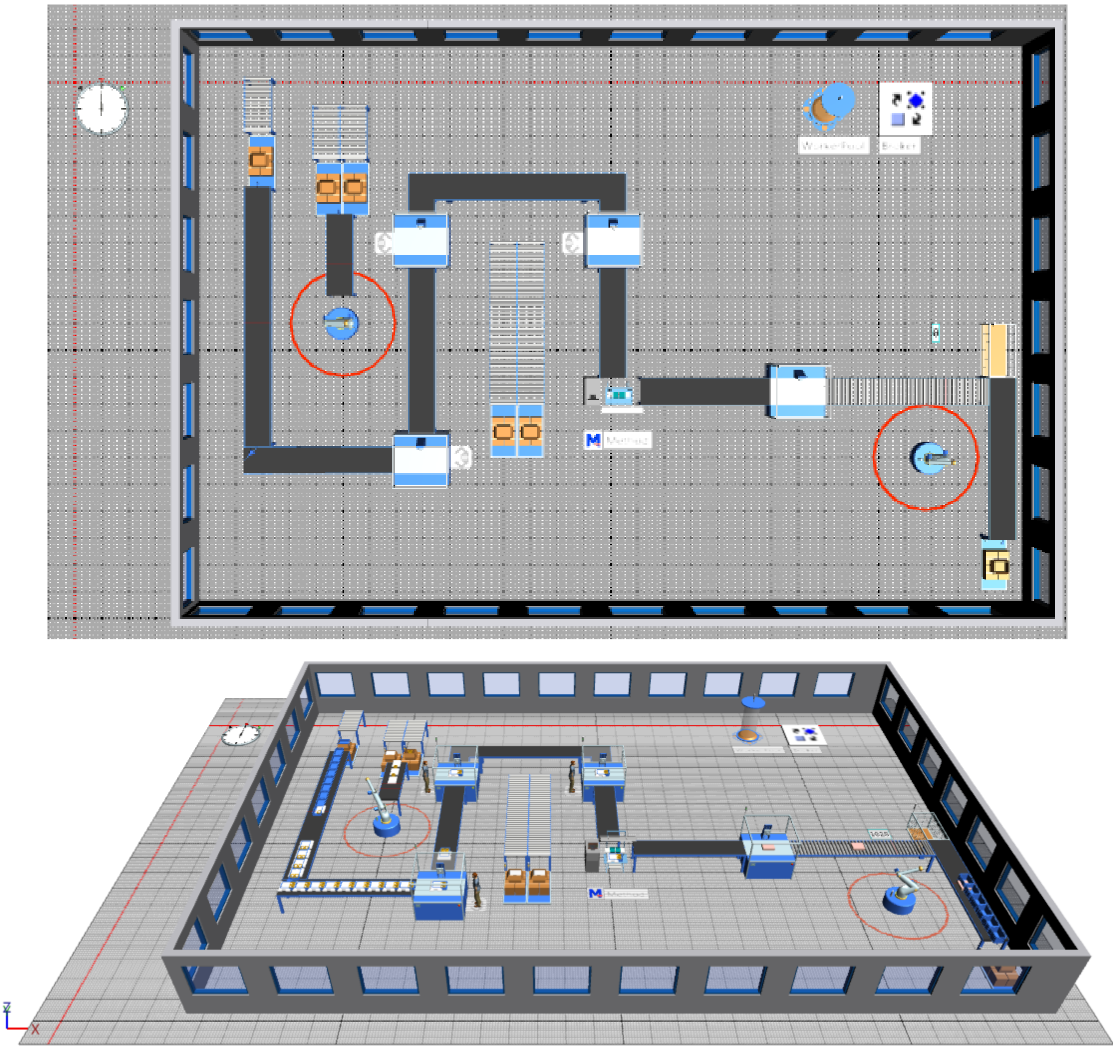

Fig. 4 *Proposed re-layout of shoe rack assembly line using Tecnomatix plant simulation*

Resource Statistics - Drain Statistics

Object	Working	Set-up	Waiting	Stopped	Failed	Paused	Mean Life Time	Mean Exit Time	Total Throughput	Throughput per Hour	Throughput per Day
Drain	7.10%	0.00%	92.90%	0.00%	0.00%	0.00%	15:32.9581	29.9874	358	119.33333	2864

Cumulated Statistics of the Parts which the Drain Deleted

(a)

Resource Statistics - Drain Statistics

Object	Working	Set-up	Waiting	Stopped	Failed	Paused	Mean Life Time	Mean Exit Time	Total Throughput	Throughput per Hour	Throughput per Day
Drain	19.93%	0.00%	80.07%	0.00%	0.00%	0.00%	5:15.1794	10.3563	1027	342.33333	8216

(b)

Fig. 5 *Resource statistics of shoe rack assembly line using Tecnomatix plant simulation(a) Current; (b) Improved*

4. Conclusion

As shown by the suggested solutions and analyses, any company that aspires to continuously enhance its production efficiency must employ all available ways to attain this aim. At each stage of the product life cycle, optimization alternatives are assessed to increase manufacturing efficiency and save both financial and human resources. This needs both software support and managerial strategies. The simulation modelling was carried out using the company's current data, and after several observations and discussions, improvements were suggested. According to the simulation findings, the recommended new process distribution for the shoe rack assembly line highlights the differences from the existing one. Surprisingly, manufacturing capacity increases considerably, from 358 to 1027 units. Thus, it is possible to determine that numerous alterations may be implemented to increase the overall efficiency of the present assembly line in comparison to other workstations. To ensure that the reform is thorough and successful, changes must be advocated at all levels of the company, from the top down. By implementing the potential solution to solve the identified bottleneck, the company may save both financial and human resources while also reducing the time required to produce the product in issue.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Nur Asyiqah Afizul, Mohamad Ali Selimin, N.A. Pagan; **data collection:** Nur Asyiqah Afizul, Ng Khang Yinn; **analysis and interpretation of results:** Nur Asyiqah Afizul, Mohamad Ali Selimin, Ng Khang Yinn; **draft manuscript preparation:** Nur Asyiqah Afizul, Mohamad Ali Selimin. All authors reviewed the results and approved the final version of the manuscript.*

References

Abdous, M. A., Delorme, X., Battini, D., Sgarbossa, F., & Berger-Douce, S. (2023). Assembly line balancing problem with ergonomics: a new fatigue and recovery model. *International Journal of Production Research*, 61(3), 693-706. https://doi.org/10.1080/00207543.2021.2015081

Afazov, S. M. (2013). Modelling and simulation of manufacturing process chains. CIRP Journal of Manufacturing Science and Technology, 6(1), 70-77. https://doi.org/10.1016/j.cirpj.2012.10.005

Bambura, R., Sujová, E., & Čierna, H. (2020). Utilizing computer simulation to optimize furniture production system. BioResources, 15(3), 6752-6765. https://doi.org/10.15376/biores.15.3.6752-6765

Blaga, F., Stanăşel, I., Hule, V., & Pop, A. (2017). Balancing the manufacturing lines through modelling and simulation using Tecnomatix Plant Simulation. MATEC Web of Conferences, 112, 06012. https://doi.org/10.1051/matecconf/201711206012

Islam, M. S., Sarker, S., & Parvez, M. (2019). Production efficiency improvement by using tecnomatix simulation software and RPWM line balancing technique: A case study. *American Journal of Industrial and Business Management*, 9(4), https://doi.org/809-820. 10.4236/ajibm.2019.94054

Marasova, D., Saderova, J., & Ambrisko, L. (2020). Simulation of the use of the material handling equipment in the operation process. Open Engineering, 10(1), 216-223. https://doi.org/10.1515/eng-2020-0015

Maria, A. (1997). Introduction to modeling and simulation. In Proceedings of the 29th conference on Winter simulation (pp. 7-13).

Mourtzis, D. (2020). Simulation in the design and operation of manufacturing systems: state of the art and new trends. *International Journal of Production Research*, 58(7), 1927-1949. https://doi.org/10.1080/00207543.2019.1636321

Trebuna, P., Pekarcikova, M., & Edl, M. (2019). Digital Value Stream Mapping Using the Tecnomatix Plant Simulation Software*. International Journal of Simulation Modelling*, 18(1), 19–32. https://doi.org/10.2507/ijsimm18(1)455

Urban, W., & Rogowska, P. (2018). The case study of bottlenecks identification for practical implementation to the theory of constraints. Multidisciplinary Aspects of Production Engineering, 1(1), 399-405. https://doi.org/10.2478/mape-2018-0051

Vidrova, Z., Bohus, Z., & Adamko, P. (2021). Simulation as a Tool for Process Optimization in a Manufacturing Company. In SHS Web of Conferences (Vol. 92, p. 08023). EDP Sciences. https://doi.org/10.1051/shsconf/20219208023