Proceedings of the 2nd GCC International Conference on Industrial Engineering and Operations Management Muscat, Oman, December 1-3, 2024

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240016
Published: December 01, 2024

Improving Productivity of Manufacturing Systems Using Green Process Reengineering-Based Simulation Method

Husam Kaid, Hatim Al Sehli, Abdullah Al Qahtani, Khalid Al Johani and Abdulmajeed Dabwan
Industrial Engineering Department, College of Engineering, Taibah University, Medina
Saudi Arabia
hkaid@taibahu.edu.sa, Ha.m22@outlook.com, Ksrsj10200@gmail.com,
adabwan@taibahu.edu.sa

Abstract

Process reengineering is an important technique for enhancing productivity and efficiency in production lines. The purpose of this study is to demonstrate the practicality of implementing reengineering techniques in a factory in Saudi Arabia that specializes in the production of diverse painting goods. These products are subsequently distributed to warehouses located throughout different cities in the country. The plant encounters challenges that result in delays in certain orders and reduced profitability, namely due to lead time. To tackle these issues, a green re-engineering methodology based on simulation is proposed to enhance the factory's performance in terms of both economic and environmental aspects. The results demonstrated a significant enhancement in the production rate and daily profit by approximately 35.67% and 32.88%, respectively, after the implementation of the new design in comparison to the current system.

Keywords
Simulation, green process reengineering, productivity, and production lines.

1. Introduction
The green reengineering method is used to implement modifications to processes, involving the transformation of the main operations and enhancing them from both an economic and environmental standpoint. It refers to a form of process re-engineering that involves a thorough overhaul of the fundamental and auxiliary elements of operations in order to expedite the achievement of environmental sustainability objectives for economic entities. This approach is regarded as a novel perspective on enhancing performance and its techniques for improving productivity, efficiency, and effectiveness. Furthermore, it helps to mitigate environmental issues and achieve efficient resource and energy utilization. The objective of the term "green" is to convert industrial processes into environmentally friendly processes, with the goal of enhancing both productivity and the working environment for employees. The proposed technique for green process reengineering primarily relies on a systematic and results-oriented approach implemented within the economic entity. For the successful implementation of green process reengineering, it is essential to adhere to the following steps: (1) Evaluation of processes that exhibit green process characteristics; (2) Integration of product-related processes with environmental aspects; (3) Implementing green reengineering processes; (4) Design and implement training courses and change management strategies; and (5) Monitoring performance and enhancing processes.

The concept of reengineering can be implemented in various ways and areas. Reengineering projects are distinguished by the diverse range of methodologies employed by researchers. (Nguyen and Do, 2016) described a methodology for transforming a traditional production model into a more efficient and simplified model. A case study was done to examine the implementation of lean concepts in the re-engineering process of an electronics manufacturing line. (Digitalleather *et al.*, 2017) conducted a comprehensive analysis of the current state of the automotive industry in the

Republic of Serbia, specifically focusing on the reengineering process. (Palasri, 2021) employed business process reengineering (BPR)-based redesign heuristics to enhance an existing production line process. In their approach, they used an evaluation technique and fit-gap analysis. (Damyanova-Bakardzhieva, 2020) conducted a study that presents the making of Bulgarin bread as a case study. The aim of this study is to clarify the importance of business process reengineering and provide evidence of its ability to generate significant effects on the industrial sector. (Hraiga et al., 2023) applied the GPRE to optimize production, reduce waste, increase profitability, gain a competitive edge, and promote environmental sustainability inside the organization. (R. Hraiga *et al.*, 2023) combined the balanced scorecard methodology with process re-engineering technologies in order to enhance the efficiency of plant project samples. (Balan, 2017)devised a methodology that combines process reengineering and simulation technology to address bottlenecks. A manufacturing facility specializing in ceramic fiber products conducted the study, with a specific focus on thermal insulation solutions. (Calderón-Andrade, Hernández-Gress and Montufar Benítez, 2020) used a reengineering method with simulation modeling to demonstrate the effectiveness of reengineering in the footwear sector. Their aim was to provide enhancements to the problematic area and the production decoration line, and then evaluate these suggested modifications in comparison to the current process.

This study presents a specific case study of X Factory, a major manufacturing plant in Saudi Arabia that specializes in producing a wide range of painting products. Multiple warehouses located in different cities throughout the country receive these products. The plant faces challenges that result in delays in certain orders and reduced profitability, namely due to lead time. To address these issues, the aim of this paper is to analyze the factory's existing performance using simulation based on reengineering techniques to reduce lead time and increase factory productivity.

2. Methodology

In this section, the methodology of the study is depicted in Figure 1. Methodology refers to the specific strategies and procedures employed to identify, select, manipulate, and analyze data within a study.

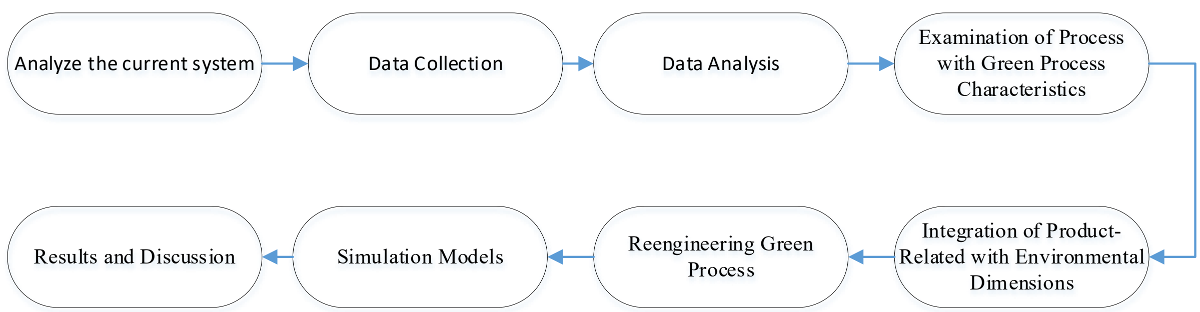

Figure 1. The methodology of the study.

2.1 Analysis of Current System

Initially, it is imperative to understand our system completely, including its sequential operations and the methodology for gathering data through the use of flow process charts and time and motion studies. Figure 2 displays the flow process chart of the existing system, encompassing material preparation, mixing procedures, labeling, and paint packing. The materials are obtained from warehouses, transferred to the manufacturing area, and mixed in a designated tank. Labels and bags are deposited into barrels, consequently completing the first mixing. Next, the second mixture is applied, and a sample is extracted to assess the viscosity and gloss of the paint. The barrel is filled with paint, hermetically sealed, and positioned on a loading platform. Subsequently, the pallet is conveyed through the use of a forklift and positioned into the product warehouse.

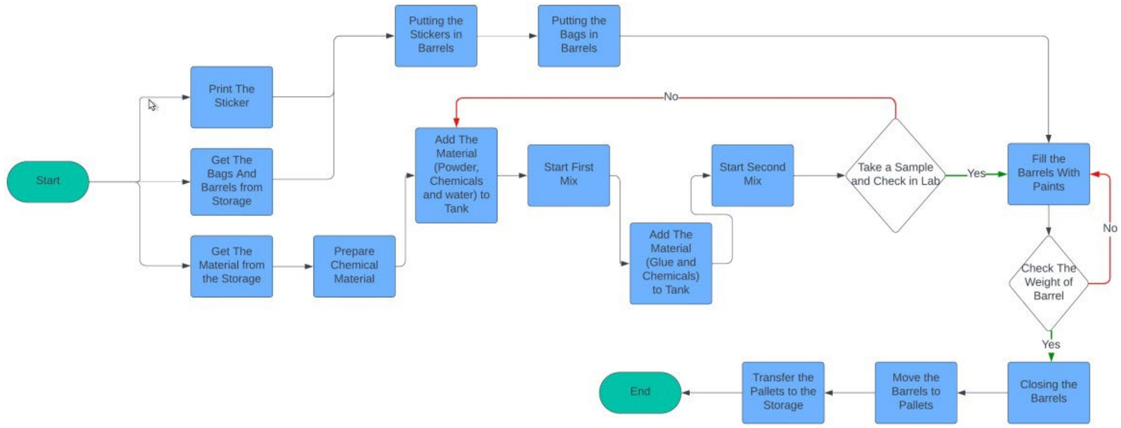

Figure 2. Flow process chart the production line.

The tool examines work procedures in a manufacturing process by specifically considering the movement and duration needed for each procedure. The flow process chart is utilized to identify the procedures that necessitate attention and to ascertain their duration. Table 1 displays a process diagram with activity descriptions, time, distance, and activity type. Each activity possesses a distinct classification based on its working method, guaranteeing the production line's efficiency and precision in analysis.

2.2 Data Collection

Data was collected for operations in the production line. The measurement was conducted on pallets containing 36 barrels of paint, with a small amount retrieved from one barrel. Every production line is equipped with a tank of varying dimensions. There are four tanks with capacities of 5 tons, 10 tons, and 3.5 tons each. The tanks have varying capacities, with the ability to create 6 pallets for 5 tons, 12 pallets for 10 tons, and 4 pallets for 3.5 tons. There are a pair of forklifts present on the production line that are responsible for transporting the pallets to the warehouse. A total of 50 samples were recorded using a timer to track the duration of each operation on the production lines. There are 50 samples allocated for each of the following processes: putting materials, first mixing, putting other materials, second mixing, lab testing, filling process, closing process, transfer operation, moving the product to the pallet, and forklift transportation. The purpose of collecting these samples was to determine the lead time for the current processes.

2.3 Data Analysis

The 50 gathered readings for each process of the current production line were examined in this section to determine the production lead time. Table 2 displays the time required for the production line to complete one pallet, which contains 36 barrels, for various weights of 5 tons, 3.5 tons, and 10 tons. Furthermore, by engaging in discussions with the factory's expert engineer, a benchmark has been set for the duration needed to produce the product on the production line. Table 3 provides the specific time estimations for tanks weighing 5 tons, 10 tons, and 3.5 tons. Each tank comprises two stages: product preparation, barrel storage, and warehouse transportation. Hence, upon comparing the standard time with the lead time for all production lines, it can be deduced that the factory is encountering an issue with the production lines since the computed lead time significantly exceeds the standard time.

Table 1. Motion and time study for the current production line

Step #	Activity description	Time (Min)	Distance (meters)	Operation	Transport	Inspection	Delay	Storage
1	Move the Raw Material (Powder- Chemicals) form the storage To Production Hall	1.20	52		x			
2	Move the Barrels and Bagsform the storage to Production Hall	1.39	87		x			
3	Print the Stickers	7.39	0	X				
4	Add the Material to themixing Machine (Powder-Water-Chemical)	50.10	1	X				
5	Begin the First Mix	33.47	0	X				
6	Putting the stickers in theBarrels	0.15	2	X				
7	Move the barrels underthe Mixing machine	1.35	39		x			
8	Putting the Bags in the Barrels	1.05	2	X				
9	Add the Material to themixing Machine (Glue-Chemical)	15.19	1	X				
10	Begin the Second Mix	11.09	0	X				
11	Take a sample and check in laboratory	8.51	17			x		
12	Filling the Barrelswith paints	0.22	0	X				
13	Check the Weightof Barrels	0.03	0			x		
14	Closing the Bag	0.20	2	X				
15	Closing the Barrels	0.12	3	X				
16	Move the Barrels to thePallets	0.10	1		x			
17	Move the Pallets to theStorage	1.30	38		x			
18	Storage The Pallet	0.10	0					x
Value Added Time		127.62						
Non-Value-Added Time		5.34						

Table 2. Lead time for the current production line

NO. of Tanks Tons (Tanks)	Average Preparing Timeof raw materialsper Pallet (Min)	Average Time of Filling per Pallet (Min)	Average Moving time per Pallet by Forklift (Min)	Total Lead Time per Pallet (Min)
5 tons (1, 2)	18.77	18.50484	1.2294	38.50424
5 tons (3, 4)	17.7	21.86016	1.2294	40.76556
5 tons (5, 6)	19.27	19.89792	1.2294	40.09732
5 tons (9, 10)	18.15	16.9242	1.2294	36.28476
3.5 tons (7, 8)	17.876	18.95136	1.2294	37.97276
10 tons (11, 12)	11.015	18.16092	1.2294	30.30932

Table 3. Standard time and actual lead time for the current production line

Tanks	Time for Preparati on in Hour	Time for Preparatio n in Min	No of Pallet	Total Time	Time to Fill & Store in Hour	Time to Fill & Store in Min	No of Barrel	Total Standard Time	Actual lead time
5-ton	1:45	105	6	17.5	0.7	40	36	19	39.78
10-ton	2:15	135	12	11.25	1:10	70	36	13	30.31
3.5-ton	1:30	90	5	18	0.5	32	36	19	37.97

Subsequently, in order to verify the accuracy of our data and eliminate any potential patterns, we conducted an analysis and constructed scatter diagrams for each tank type and line. Furthermore, through the utilization of the input analyzer add-ons given by Arena Software, all the data has undergone thorough evaluation and adjustment to identify and establish the mathematical representations for each process in every production line. Figure 3 presents a concise summary of the information provided in this section.

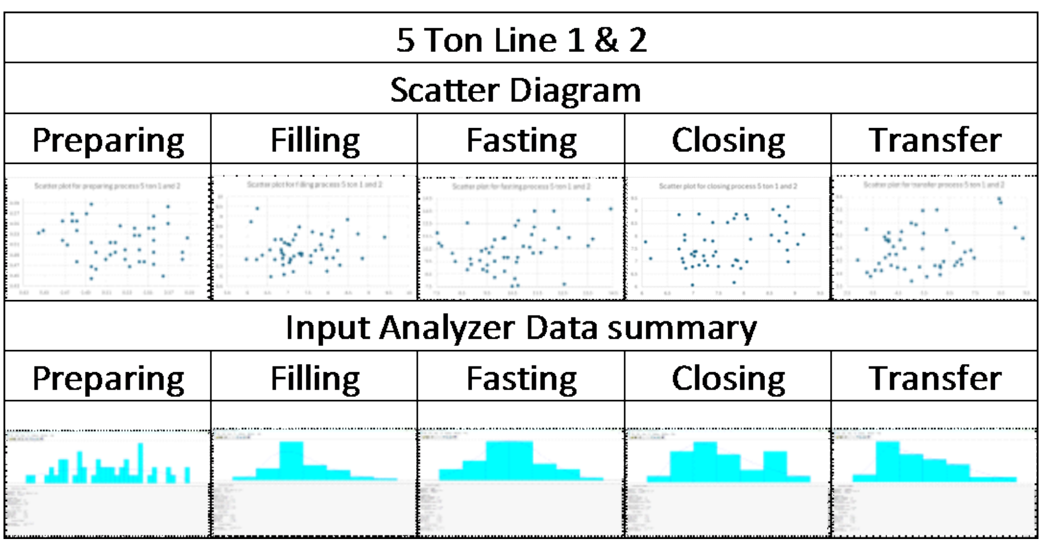

Figure 3. Scatter plot for and Input Analyzer results for the collected data

2.4 Examination of Process with Green Process Characteristics

During this stage, we thoroughly examine all the operations in the factory's production line to ensure that they meet the criteria of the five green process characteristics: necessity, efficiency, effectiveness, flexibility, and measurability. Any operations that fail to meet these criteria are transferred to the next stage and must be reported to the factory's engineers. The engineers will then work on implementing effective alternatives to improve these operations. Table 4 displays the test outcomes for five operations: paint preparation, barrel filling, bag tying in barrels, barrel closure, and barrel transfer to the pallet.

Table 4. Testing factory operations for compliance with green process characteristics

Characteristics / Operation	Necessary	Efficient	Effective	Flexible	Measurable	Test Results
Preparing the Paints	□	□	□	□	□	Not Passing
Filling the Barrels	□	□	□	□	□	Passing
Tying the bag in the Barrels	□	□	□	□	□	Passing
Closing the Barrels	□	□	□	□	□	Passing
Transferring the Barrels	□	□	□	□	□	Passing

2.5 Integration of Product-Related with Environmental Dimensions

After completing the previous stage, any operations that do not align with the green process reengineering characteristics will be transferred to this stage for the purpose of examining their activities and the corresponding environmental aspects. Here, the preparation operation lacks the necessary features, and hence it comprises five primary activities:

1. Placing the materials (powder, water, and chemical materials) into the tank.
2. Start with the initial blending procedure.
3. Adding the remaining materials (glue and chemical materials) into the tank.
4. Conduct the final mixing procedure.
5. Take a sample of the product and conduct tests in the laboratory.

These five activities are considered in the preparation operation. Each of these activities is studied, and upon examination, it is evident that the first activity poses the main problem for this preparation operation. This is because when the work begins, the worker needs to request pallets containing the materials from storage. These materials consist of four types of powder, A, B, C, and D, which need to be placed inside the tanks. Each pallet contains a large number of small bags, each weighing 25 kg, of each type. Consequently, the worker needs to put a specific number of each type into the 10-ton tank. For instance, approximately 116 bags of type B need to be placed in the tank. This task takes a significant amount of time to complete. Therefore, this paper will focus on finding alternative ways to reduce the time required to complete this activity and increase productivity. There are two recommended solutions for solving this problem:

1. Use a large bag capable of holding 1000 kg of powder to fill the tanks.
2. Load the tanks using a barrel with a capacity of 250 kg of powder.

We will thoroughly explain these two solutions and their practical implementation in the next phase of green process reengineering.

2.6 Reengineering Green Process

The main problem in the production line is the lengthy process of filling the tank with materials for the mixing procedure, resulting in a detrimental impact on production efficiency and financial gains. The paper presents a discussion of two options, along with the estimated time it would take to produce each one. Strict compliance with safety procedures and the utilization of protective equipment are necessary in order to prevent the occurrence of detrimental illnesses, including: A mask hat is used to avoid inhaling powder vapor when opened, wearing gloves to avoid the risk of cuts and to keep the powder from sticking to our hands, wearing a robe to protect our clothes from getting dirty, and wearing goggles to avoid the powder vapor when opening the bags. Two alternatives were developed and assessed to determine the most effective one.

The first alternative: Barrels were replaced with large bags, and the initial alternative utilized the same four fundamental materials. The packing method involved loading the large bag onto the forklift and then filling it by elevating the tiny bags to the same height as the large bags. The small bags were then opened and their contents were emptied into the large bags, following the procedure depicted in Figure 4(a). Once the packing procedure is finished, the large bags are placed on pallets and delivered to the work area by forklifts. Subsequently, the bags are hoisted into the tank using a hook, as depicted in Figure 4(b). In this scenario, we require three workers, similar to the previous alternative. One of them will be responsible for operating the forklift, while the other two workers will be tasked with opening the large bag from its bottom and transferring its contents into the tank, as depicted in Figure 4(c). This alternative is repeated 30 times to confirm the precision of the information. It has been accomplished for tanks of various capacities, including 3.5, 5, and 10 tons.

(a) (b) (c)

Figure 4. Alternative one: (a) large bag and the materials are transferred to the work area, (b) the forklift is raising the bags using a hook, and (c) pouring the bags containing the materials into the tank involves cutting the ends of the bags.

The second alternative: The second alternative utilizes large barrels, originally designed for transporting various materials, as an alternative for powder bags. The first alternative involved reusing large drums typically utilized for different chemical substances and adapting them for this particular solution. First, we identified the four distinct types of powder utilized, namely A, B, C, and D. Subsequently, we thoroughly cleansed the barrels and made them ready for the filling procedure. Afterwards, a forklift was employed to transfer the barrels to the preparation area, as illustrated in Figure 5(a). Next, the bag is elevated to the same height as the barrel, and then it is unsealed in order to insert it into the barrel. Each particular type of tank will require a predetermined quantity of drums. This process is iterated until the desired quantity is achieved, as depicted in Figure 5(b). Once the filling procedure was finished, the barrels were hauled to the work area using forklifts, and subsequently hoisted into the tank. For this task, we required a team of 3 workers. One worker operated the forklift while the other two workers emptied the barrel into the tank, as depicted in Figure 5(c). We repeated this process 30 times to ensure the accuracy of the data. However, this method was only applicable for tanks with a capacity of 3.5 tons and 5 tons. For a 10-ton tank, this approach would not be effective due to the large number of drums, which would occupy too much space and require a significant amount of time to complete.

(a) (b) (c)

Figure 5. Alternative two: (a) the drums and materials are transferred to the work area, (b) filling the drums with all the materials in a specific arrangement, and (c) pouring the drums that contain the materials into the tank.

2.7 Simulation Models

This section involves analyzing the existing system and potential alternatives using Arena Software. This software allows us to simulate our production line so that we can accurately represent the actual process and make enhancements and modifications. We employed green process reengineering to evaluate various parameters of the conceptual simulation model. The plant design and process sequence diagram depicted in the flowchart have been duly considered. As previously mentioned, there are a total of six mixing machines. We allocate a separate line for each machine, each containing four processes. Individual workers staff each line. Each mixing machine will have a total of five workers operating beneath it. The workers are working 8-hour shifts, which include a 60-minute break. Each mixing machine goes through several distinct processes, including paint preparation, drum filling, bag tying, cap sealing in the drums, and ultimately, drum transportation to the loading platform. Figure 6 depicts the simulation model of the existing system, which comprises a total of 47 modules.

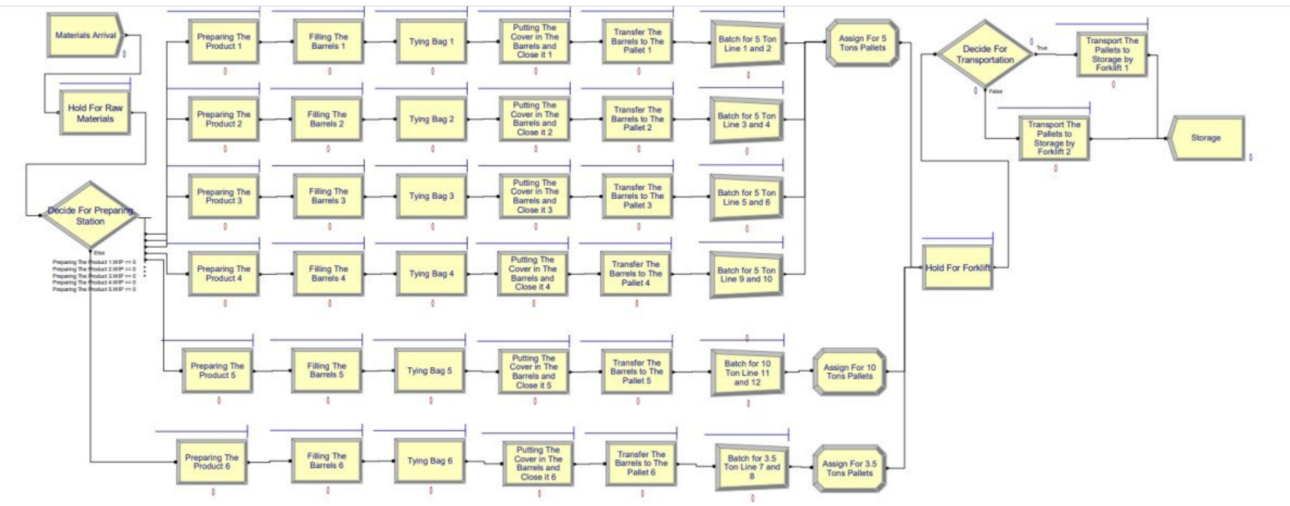

Figure 6. Arena model for the current system.

3. Results and Discussion

This section will analyze the existing system and the two alternatives that will be evaluated via Arena software. The performance of each alternative will be evaluated based on the results obtained from running the current model and the alternative models. The simulations were conducted with 800 replicates and an 8-hour work shift. The output analyzer in Arena Software will be used to compare the outcomes of the different models. Each alternative will be tested using tanks of different capacities, starting with a 3.5-ton tank, then a 5-ton tank, and finally a 10-ton tank. By performing a one-way ANOVA test using the Output Analyzer, the data results files for the current, alternative 1, and alternative 2 models were selected for tanks with capacities of 3.5, 5, and 10 tons. The analysis demonstrates that the null hypothesis is rejected (H0: all the means are equals), indicating that the means are not equal at a significance level of 0.05. Furthermore, there are significant differences between the models. The current system yields a final output of 171 pallets per shift for all tank types, but alternative 1 yields a higher output of 232 pallets per shift. Alternative 2 produces 190 pallets per shift for tanks weighing between 3.5 and 5 tons. In contrast, it can accommodate 211 pallets per shift for tanks weighing 10 tons. Figure 7 shows the comparison between the final output for the current, alternative 1, and alternative 2 models. Furthermore, the lead time for all the models was compared. According to the current model, the time it takes for all tanks to be produced is 38.05676 min for a 3.5-ton tank, 36.30 min for a 5-ton tank, and 30.40532 min for a 10-ton tank. These times are deemed to be exceedingly elevated. Alternative 1 resulted in a reduction in lead times compared to current models. Specifically, the lead time for a 5-ton tank decreased to 31.44 min, a 3.5-ton tank decreased to 34.60 min, and a 10-ton tank decreased to 26 min. Regarding alternative 2, the model of 3.5 tons will require 36.36 min, whereas the model of 5 tons will require 33.36 min. In summary, after comparing the times for each model, it can be concluded that alternative 1 is the superior choice. Figure 8 provides a concise summary and presentation of the lead time for each model.

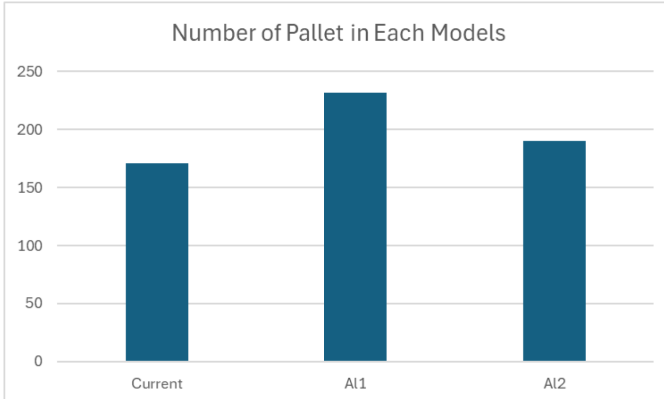

Figure 7. Comparison between final output for the current, alternative 1, and alternative 2 models.

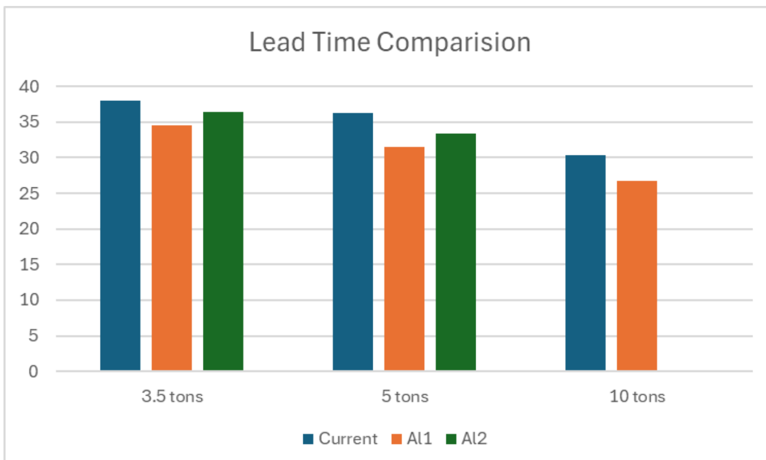

Figure 8. Comparison between the lead time for the current, alternative 1, and alternative 2 models.

4. Conclusion

This paper proposes a green re-engineering methodology based on simulation to enhance the factory's performance in terms of both economic and environmental aspects. The main problem in the selected factory is the lengthy process of filling the tank with materials for the mixing procedure, resulting in a detrimental impact on production efficiency and financial gains. To solve this problem, we proposed a solution, which involves using large bags. This approach minimizes time waste and enhances productivity. By implementing this alternative, the factory can expand its operations, increase the number of production machines, and consequently increase the quantity of materials produced. The results demonstrated a significant enhancement in the production rate and daily profit by approximately 35.67% and 32.88%, respectively, after the implementation of the new solution in comparison to the current system.

References

Balan, S., Using simulation for process reengineering in refractory ceramics manufacturing—a case study', *International Journal of Advanced Manufacturing Technology*, 93(5–8), pp. 1761–1770, 2017. Available at: https://doi.org/10.1007/S00170-017-0602-9.

Calderón-Andrade, R., Hernández-Gress, E.S. and Montufar Benítez, M.A., Productivity Improvement through Reengineering and Simulation: A Case Study in a Footwear-Industry', *Applied Sciences 2020, Vol. 10, Page 5590*, 10(16), p. 5590., 2020. Available at: https://doi.org/10.3390/APP10165590.

Damyanova-Bakardzhieva, M., Opportunities for process reengineering in Bulgarian bread production (a case study)', *IOP Conference Series: Materials Science and Engineering*, 878(1), p. 012081, 2020. Available at: https://doi.org/10.1088/1757-899X/878/1/012081.

Digitalleather, N.B. *et al.*, Evaluation of the current state of an automotive factory in the Republic of Serbia in the course of the reengineering process', *researchgate.netS Nikezić, M Dželetović, N Bandukaresearchgate.net* , 2021. [Preprint]. Available at: https://www.researchgate.net/profile/Nikola-Banduka/publication/319715141_Evaluation_of_the_current_state_of_an_automotive_factory_in_the_Republic_of_Serbia_in_the_course_of_the_reengineering_process/links/5acb66a74585151e80a9f64b/Evaluation-of-the-current-state-of-an-automotive-factory-in-the-Republic-of-Serbia-in-the-course-of-the-reengineering-process.pdf (Accessed: 13 July 2024).

Hraiga et al., Improving Productivity Using Green Process Reengineering Technology.', *Polish Journal of Environmental Studies*, 32(5), pp. 4037–4049, 2023. Available at: https://doi.org/10.15244/pjoes/166164.

Hraiga, R. *et. al.* Balanced scorecard integration and green process re-engineering to optimize the performance of economic units', *cyberleninka.ruRA Hraiga, AMMA Fadel, AA AbbasEconomics, Management and Sustainability, 2023•cyberleninka.ru*1)8 ,), pp. 16–33, 2023. Available at: https://cyberleninka.ru/article/n/balanced-scorecard-integration-and-green-process-re-engineering-to-optimize-the-performance-of-economic-units (Accessed: 11 August 2024).

Nguyen, M.N. and Do, N.H., Re-engineering Assembly Line with Lean Techniques', *Procedia CIRP*, 40, pp. 590–595, 2016. Available at: https://doi.org/10.1016/J.PROCIR.2016.01.139.

Palasri, Y., Production line process improvement with process reengineering - a case study in garment factory', *Chulalongkorn University Theses and Dissertations (Chula ETD)* [Preprint]. 2021. Available at: https://doi.org/10.58837/CHULA.THE.2021.120.

Biographies

Husam Kaid is an assistant professor in the Department of Industrial Engineering, College of Engineering, at Taibah University in Saudi Arabia. In 2021 and 2015, he received his PhD and MS in Industrial Engineering from King Saud University in Saudi Arabia, respectively. In 2010, he received a BS in Industrial Engineering from Taiz University in Yemen. His current research interests include Petri net theory and application, supervisory control of discrete event systems, workflow modeling and analysis, system reconfiguration, systems simulation, operations research, optimization of manufacturing operations, flexible manufacturing systems and cellular manufacturing systems, product design analysis, and applications of decision support systems in manufacturing.

Hatim Al Sehli is a student in the Department of Industrial Engineering, College of Engineering, at Taibah University in Saudi Arabia. In 2024, he received a BS in Industrial Engineering from Taibah University in Saudi Arabia. His current research interests include systems simulation, operations research, optimization techniques, and manufacturing systems.

Abdullah Al Qahtani is a student in the Department of Industrial Engineering, College of Engineering, at Taibah University in Saudi Arabia. In 2024, he received a BS in Industrial Engineering from Taibah University in Saudi Arabia. His current research interests include systems simulation, operations research, and applications of decision support systems in manufacturing.

Khalid Al Johani is a student in the Department of Industrial Engineering, College of Engineering, at Taibah University in Saudi Arabia. In 2024, he received a BS in Industrial Engineering from Taibah University in Saudi Arabia. His current research interests include systems simulation, operations research, optimization techniques, flexible manufacturing systems and cellular manufacturing systems.

Abdulmajeed Dabwan is an assistant professor in the Department of Industrial Engineering, College of Engineering, at Taibah University in Saudi Arabia. In 2021 and 2016, he received his PhD and MS in Industrial Engineering from King Saud University in Saudi Arabia, respectively. In 2010, he received a BS in Industrial Engineering from Taiz University in Yemen. His current research interests include surface machinability of the additively manufactured components, sheet metal forming in manufacturing technology, CNC machining, design and analysis of experiment in manufacturing systems, optimization techniques, simulation, manufacturing processes, operations research, human factor engineering, and Quality engineering.