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DESIGN AND OPTIMIZATION OF LAYOUT TO REDUCE CYCLE TIME AND HUMAN RESOURCE USING TECNOMATIX PLANT SIMULATION

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Abstract
This research paper is about efficient design and optimization of manufacturing layout playing a critical role in improving productivity and reducing operational costs in the manufacturing industry. This study focuses on utilizing Tecnomatix Plant Simulation software to enhance the layout design process and minimize cycle time while optimizing human resource allocation. The objective is to develop an efficient layout that enables a smooth material flow and minimizes unnecessary movement within the production facility. The research methodology involves analysing the existing cellular batch manufacturing layout and transforming it into a linear line of material flow. By adopting this approach, the study aims to eliminate bottlenecks, reduce waiting time, and enhance overall production efficiency. Additionally, the optimization process includes determining the appropriate workforce allocation to ensure optimal utilization of human resources. The outcomes of this study are expected to contribute to the manufacturing industry by providing insights into effective layout design and resource optimization strategies. The research findings will provide valuable insights into the relationship between design, layout, and human resource allocation in manufacturing facilities. By leveraging Tecnomatix Plant Simulation, manufacturers can make informed decisions to optimize operations, reduce cycle time, and enhance overall productivity. The results will contribute to the field of industrial engineering and support the continuous improvement efforts of manufacturing organizations.

Keywords: Design optimization, Layout optimization, Cycle time reduction, Human resource allocation, Tecnomatix Plant Simulation, Manufacturing productivity.

I. Introduction

The constant pursuit of improving manufacturing productivity has led researchers and practitioners to explore innovative strategies and technologies. One such approach involves the design and optimization of layout to reduce cycle time and determine the appropriate human resource allocation. In this study, we focus on utilizing Tecnomatix Plant Simulation, a powerful simulation software, to enhance manufacturing productivity by optimizing layout design and human resource allocation. Efficient layout design plays a crucial role in streamlining production processes and minimizing cycle time. By strategically placing workstations, equipment, and material handling systems, manufacturers can minimize material movement, reduce waiting time, and improve overall operational efficiency. The optimization of layout design requires a comprehensive understanding of the manufacturing environment, process flows, and constraints. Simultaneously, appropriate workforce allocation is vital to ensure the smooth functioning of the production line.

The transformation from a cellular batch material flow to a linear form of material flow involves reorganizing the layout of a manufacturing facility to optimize the movement of materials and streamline production processes. In a cellular batch layout, production is organized into cells or workstations where groups of workers handle specific tasks or processes. Materials are typically moved between cells in batches, resulting in potential bottlenecks, delays, and inefficient material flow. To address these challenges, the transformation to a linear material flow layout aims to create a continuous and streamlined flow of materials through the production process. This is achieved by reorganizing the layout into a linear arrangement where materials move sequentially from one process step to the next, without the need for batching or excessive movement.

Inadequate human resource allocation can lead to inefficiencies and increased costs. Overstaffing can result in unnecessary expenses, while understaffing can cause production delays and lower productivity. By allocating the right number of employees to each task, manufacturers can optimize resource utilization and minimize labour costs. When human resources are allocated optimally, the production process runs smoothly, with minimal disruptions or delays. This leads to improved overall productivity, as workers are able to focus on their assigned tasks without unnecessary interruptions. Proper resource allocation also facilitates better coordination and collaboration among team members, leading to increased efficiency.

Tecnomatix Plant Simulation offers a powerful toolset for analysing and optimizing manufacturing systems. Through the creation of virtual models that simulate real-world production environments, researchers and practitioners can experiment with different layout configurations, test various workforce allocation strategies, and evaluate the impact on cycle time and productivity. The objective of this research is to demonstrate the effectiveness of utilizing Tecnomatix Plant Simulation in enhancing manufacturing productivity through layout optimization and human resource allocation. By conducting a case study in a real manufacturing setting, we aim to showcase the practical applicability and benefits of this approach. The results obtained from the simulation experiments will provide insights into the optimal layout design and human resource allocation strategies that can significantly reduce cycle time and improve overall productivity.

II. Literature Survey

[1]. The need and driving forces for adopting digital manufacturing, as well as to discuss the transformation of manufacturing to smart manufacturing. It also explores the current applications and future scope of digital manufacturing. The convergence of natural, built, and digital environments is shaping economies and societies, leading to a shift towards smart living and mass customization. Digital manufacturing, enabled by advancements in technology, allows for efficient product conception, shorter timeframes, and effective management of the entire product lifecycle. It emphasizes the importance of leveraging digital tools and processes to optimize manufacturing and meet evolving customer demands.

[2].The analysis of the production process in model optimization through plm software module Tecnomatix Plant Simulation. The focus is on proposing optimization measures provided by the software package. The paper begins by introducing relevant theoretical concepts but primarily centres on the analysis and design of a simulation model. The software module enables users to create digital models of the manufacturing environment, including machinery, equipment, and workflow. To analyse the production process of a company using Siemens Tecnomatix Plant Simulation module. The

application of Tecnomatix Plant Simulation in analysing and designing a simulation model for the production process. The graphical solution showcases the potential improvements in the company's production system, highlighting the effectiveness of the proposed optimization measures.

[3].This emphasizes the benefits and effectiveness of virtualization in improving the overall efficiency of the production line. To demonstrate the application of discrete simulation, specifically using Tecnomatix Plant Simulation software, to optimize a production line in the Manaus Industrial Pole. It aims to understand the parameters involved and guide the composition of the production line for improved efficiency. The modelling using Plant Simulation successfully virtualized the production process, with a maximum difference of 1.07% compared to the real process. This highlights the effectiveness of discrete simulation in optimizing processes and achieving cost reduction or capacity increase in industrial settings.

[4].To utilize the Tecnomatix Plant Simulation software for conducting milk run testing. The aim is to evaluate the effectiveness and efficiency of milk run logistics in improving material flow and reducing transportation costs in a manufacturing environment, improving delivery times, and optimizing material flow. To demonstrates the successful application of Tecnomatix Plant Simulation software for milk run testing. The results indicate improved material flow, reduced transportation costs, and enhanced efficiency in the manufacturing process. Milk run logistics proves to be a valuable strategy for optimizing material handling and transportation in manufacturing operations.

[5]. Aimed to Increase the efficient manufacturing process using the Tecnomatix Plant Simulation software module and another management method. The objective is to analyse and optimize the manufacturing process by integrating the capabilities of Tecnomatix Plant Simulation with another management method. To analyse and improve the production and assembly line for manufacturing car handles and their components. The study focuses on using simulation models in Tecnomatix Plant Simulation and the Hoshin method to increase efficiency in the manufacturing process. By analysing the production and assembly line and implementing simulation models and the Hoshin method, the study aims to improve the efficiency of the manufacturing process for car handles. The findings contribute to achieving maximum productivity and cost-effectiveness in the production process, aligning with the overall goals of businesses in the industry.

[6] To analyse and optimize the production process through the integration of Tecnomatix Simulation software and the RPWM technique. To improve the productivity of a sewing line in VIP Industries Bangladesh by balancing the assembly line for Duffle Trolley Bags. The study aims to achieve high production rates, minimize costs, and meet daily production targets while maintaining quality. The study successfully applies the RPWM line balancing technique and Tecnomatix simulation software to optimize and improve the balance line layout of the sewing line. The findings demonstrate that by implementing the proposed improvements, the company can achieve high production rates, minimize costs, and meet daily production targets while ensuring product quality.

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III. Methodology

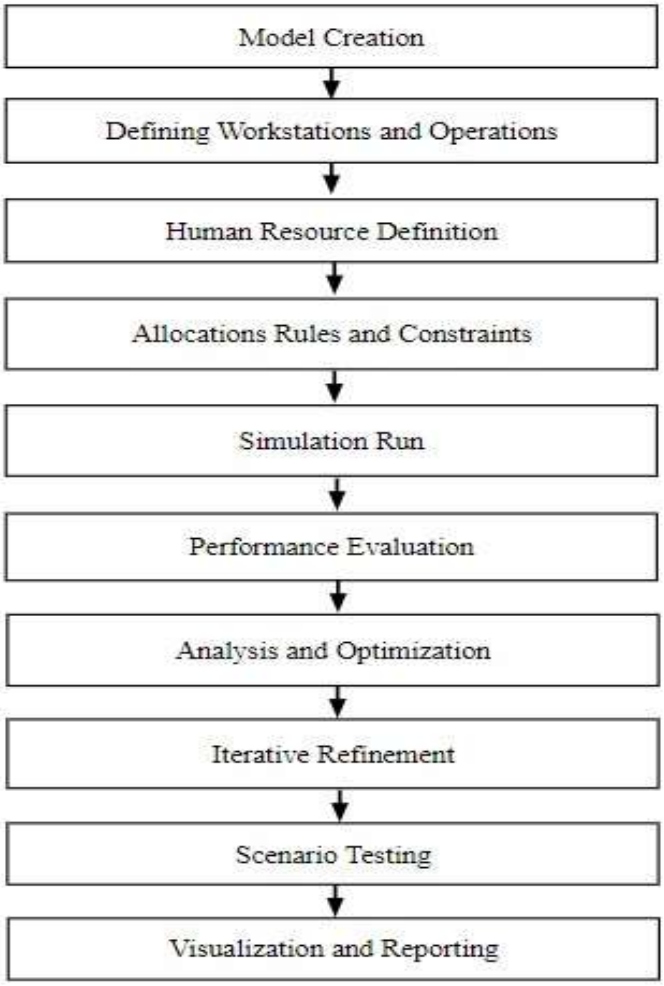

Figure 1: Process carried out in Tecnomatix Plant Simulation Software

The process followed to tackle the challenges faced by manufacturing unit using Tecnomatix Plant Simulation involves utilizing the software to optimize the allocation of workforce and reduce cycle time within a manufacturing environment. The steps involved in this process are as follows:

1. **Model Creation**: The first step is to create a virtual model of the manufacturing facility using Tecnomatix Plant Simulation. This includes defining the layout, machines, equipment, and production lines within the simulated environment.

2. **Define Workstations and Operations**: Once the model is created, the next step is to define workstations and operations within the simulated manufacturing process. This involves identifying the specific tasks and operations that need to be performed at each workstation.

3. **Resource Definition**: In Tecnomatix Plant Simulation, resources are defined as the human workforce available for allocation. The software allows for defining the number of workers, their skills, shifts, and availability. The skills defined can be specific to certain operations or general to cover a range of tasks.

4. **Allocation Rules and Constraints**: The allocation process involves setting up rules and constraints to guide the resource allocation decisions. These rules can include factors such as skill requirements, work schedules, task dependencies, and production targets. Constraints ensure that the allocation adheres to operational limitations and regulations.

5**. Simulation Run**: Once the model, workstations, operations, resources, and rules are defined, a simulation run is performed using Tecnomatix Plant Simulation. The simulation runs multiple iterations, simulating the manufacturing process and resource allocation based on the defined parameters.

6. **Performance Evaluation**: During the simulation run, the software collects data on various performance metrics, including cycle time. Cycle time refers to the total time required to complete a task or operation. The simulation provides insights into the impact of resource allocation on cycle time, highlighting areas where optimization is needed.

7. **Analysis and Optimization**: After the simulation run, the collected data is analysed to evaluate the performance of the resource allocation strategy in reducing cycle time. This analysis helps in identifying bottlenecks, delays, or inefficiencies in the manufacturing process that contribute to longer cycle times. Based on the analysis, adjustments can be made to the resource allocation strategy to optimize cycle time.

8. **Iterative Refinement**: The optimization process involves making iterative refinements to the resource allocation strategy. This may include reallocating resources, adjusting task assignments, or modifying work schedules to reduce cycle time. The simulation is rerun to test the revised allocation strategy and measure its impact on cycle time.

9. **Scenario Testing**: Tecnomatix Plant Simulation allows for testing different scenarios by changing allocation parameters, introducing new constraints, or simulating alternative production scenarios. This helps in evaluating the impact of different resource allocation strategies on cycle time and aids in decision-making for optimization.

10. **Visualization and Reporting**: The software provides visualizations and reports that illustrate the resource allocation and its impact on cycle time within the manufacturing process. These visualizations help stakeholders understand the allocation decisions and support informed decision-making for optimizing cycle time.

IV. Results and Discussion

[A] To reduce the overall cycle time of a manufacturing process

The existing layout of the manufacturing unit was designed in cellular batch of material flow, i.e. the workstations of each manufacturing line are located in a cellular form. Due to cellular batch manufacturing, workstations with in each cell often handle different tasks and operation. If the workload is not balanced properly among the workstations, it can lead to bottlenecks and waiting times. Some workstations may finish their tasks faster, while others may become overwhelmed with work, causing delays in the overall process leading to waiting time.

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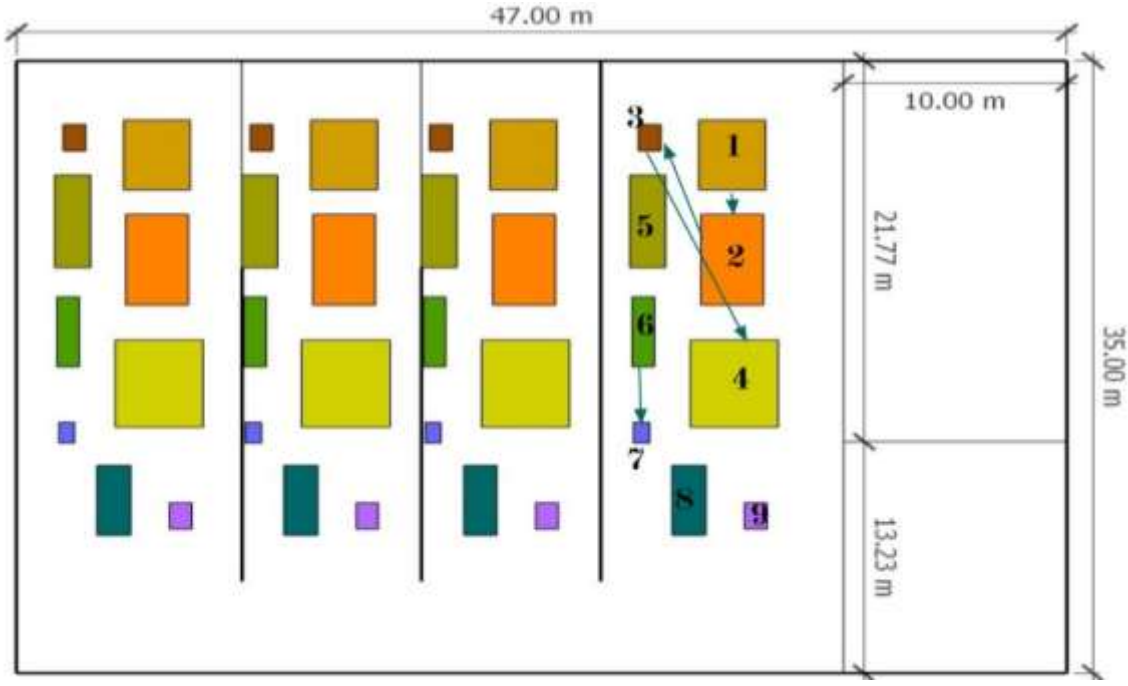

Figure 2: Existing Layout of the Manufacturing Unit

Existing Operation Cycle Time in Seconds					
Serial No	**Process**	**Process Time**	**Setup Time**	**Waiting Time**	**Total Time**
1	**AA**	60	90	0	150
2	**BB**	85	120	25	230
3	**CC**	40	60	30	130
4	**DD**	30	145	48	223
5	**EE**	65	50	45	160
6	**FF**	75	30	51	156
7	**GG**	45	38	48	131
8	**HH**	90	70	22	182
9	**II**	250	100	20	370
	Total Time	740	703	289	1732

Table 1: Cycle Time of Existing Manufacturing Process

The existing layout of manufacturing unit leads to waiting time due to uneven distribution of tasks between the workstations and the human resource, and products moving sequentially from one cell to another can lead to waiting time. Hence while designing a new layout of manufacturing unit to expand the manufacturing lines, considering the material flow to be linear form i.e. is continuous arrangement of workstations, can completely eradicate the waiting time there by reducing the overall cycle time of the manufacturing process.

Table 2: Reduced Cycle Time of the Manufacturing Process

Operation of Reduced Cycle Time in Seconds					
Serial No	**Process**	**Process Time**	**Setup Time**	**Waiting Time**	**Total Time**
1	**AA**	60	90	0	150
2	**BB**	85	120	0	205
3	**CC**	40	60	0	100
4	**DD**	30	145	0	175
5	**EE**	65	50	0	115
6	**FF**	75	30	0	105
7	**GG**	45	38	0	83
8	**HH**	90	70	0	160
9	**II**	250	100	0	350
	Total Time	740	703	0	1443

Table 2 shows the reduced cycle time for designing the manufacturing unit to expand the manufacturing line, where the total cycle time has been reduced by 4.3 minutes, and more number of products can be produced within a given timeframe, increasing overall throughput with capacity and fulfil the customer demand in faster pace.

Utilizing Tecnomatix Plant simulation software, a digital model of the manufacturing system is created. This model represents the layout, equipment, and workflows of the actual production environment. The software provides a user-friendly interface to design and visualize the system. The simulated model allows for the analysis of cycle times at various stages of the manufacturing process. By running the simulation, it is possible to observe how long it takes for products to move through each workstation, identify bottlenecks, and measure overall cycle time. The simulation provides valuable insights into areas where cycle time reduction is possible. Through visualizations, statistical data, and real-time monitoring, the software helps identify inefficiencies, waiting times, and opportunities for optimization.

Object	**Number of Entries**	**Number of Exits**	**Relative Empty**	**Relative Occupation without Interruptions**
Process	109	108	0.00%	100.00%
Process1	108	107	0.00%	100.00%
Process2	107	106	0.61%	99.39%
Process3	106	105	1.40%	98.60%
Process4	105	104	2.01%	97.99%
Process5	104	103	2.53%	97.47%
Process6	103	102	3.84%	96.16%
Process7	102	101	3.66%	96.34%
Process8	101	100	4.10%	95.90%
Process9	100	99	9.76%	90.24%

Table 3: Statistical Report from Tecnomatix Plant Simulation showing Productivity Improvement

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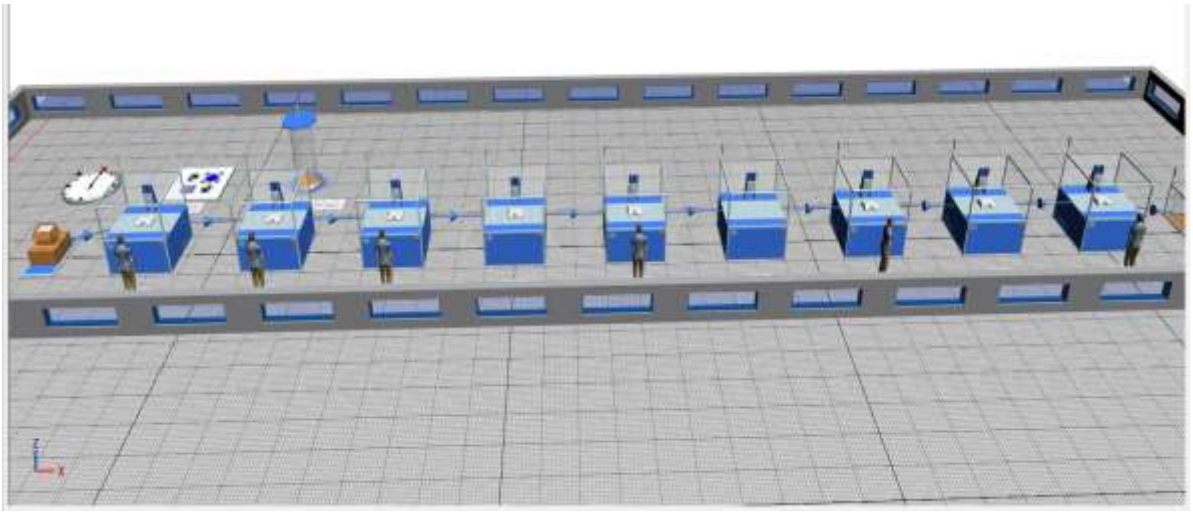

Figure 3: Model of Newly Designed Manufacturing Line in Tecnomatix Plant Simulation

The statistical report from Tecnomatix Plant Simulation shows the productivity improvement by reducing cycle time from transforming the manufacturing lines from cellular form of material flow to linear or continuous form of material flow. The total productivity has been improved by 26% in total productivity.

[B] To reduce the human resource of a manufacturing process

Simulating and analysing human resource allocation using Tecnomatix Plant Simulation software provides a valuable tool for optimizing workforce efficiency and productivity in manufacturing processes. To begin the simulation, relevant data about the human resource is inputted into the Tecnomatix Plant Simulation software. This includes information such as the number of operators, their skill levels, work schedules, and availability. A digital model of the manufacturing system is created, including the representation of the human resource. The software allows for the visualization of the human resource distribution across different workstations and shifts. The simulated model allows for the analysis of the workload on each workstation and for each operator. By running the simulation, it is possible to observe how the workload is distributed and identify potential areas of under or overutilization of human resources. The simulation helps identify bottlenecks in the production process caused by inadequate workforce allocation. By analysing the flow of work and the availability of operators at different workstations, the software can pinpoint areas where additional resources may be needed.

The existing manufacturing unit has 7 workers for each manufacturing line for the cycle time of 28.8 minutes. The overall cycle time has been reduced and optimal human resource allocation is done using Tecnomatix Plant Simulation. With help of statistical report from Tecnomatix Simulation software, the model was analysed with 4, 5, 6, and 7 workers, to find the optimal human resource required for the manufacturing process of a manufacturing unit. The Statistical Report i.e. Table 4, 5, 6 and 7 shows the number of products produced by allocating different number of workers for per shift of manufacturing unit to find the optimal human resource required for each manufacturing line of a manufacturing unit.

The statistical report clearly defines the productivity rate for each number of workers. The 4 workers allocation provides only 48% of productivity from existing productivity rate. The 5 workers allocation provides 80% productivity from existing productivity rate. The 6 and 7 workers allocation provides the equal productivity rate improved by 20% from the existing productivity rate.

Object	Number of Entries	Number of Exits	Relative Empty	Relative Occupation without Interruptions
Process	76	76	0.00%	100.00%
Process1	76	75	0.00%	100.00%
Process2	75	74	2.26%	97.74%
Process3	74	73	1.79%	98.21%
Process4	73	72	2.92%	97.08%
Process5	72	71	3.11%	96.89%
Process6	71	70	3.48%	96.52%
Process7	70	69	4.24%	95.76%
Process8	69	68	4.24%	95.76%
Process9	68	67	33.33%	66.67%

Table 4: Statistical Report for 4 Workers

Object	Number of Entries	Number of Exits	Relative Empty	Relative Occupation without Interruptions
Process	103	102	0.00%	100.00%
Process1	102	101	0.00%	100.00%
Process2	101	100	2.47%	97.53%
Process3	100	100	2.11%	97.89%
Process4	100	99	2.11%	97.89%
Process5	99	98	2.66%	97.34%
Process6	98	97	4.03%	95.97%
Process7	97	96	3.85%	96.15%
Process8	96	95	4.31%	95.69%
Process9	95	94	9.98%	90.02%

Table 5: Statistical Report for 5 Workers

Object	Number of Entries	Number of Exits	Relative Empty	Relative Occupation without Interruptions
Process	109	108	0.00%	100.00%
Process1	108	107	0.00%	100.00%
Process2	107	106	0.61%	99.39%
Process3	106	105	1.40%	98.60%
Process4	105	104	2.01%	97.99%
Process5	104	103	2.53%	97.47%
Process6	103	102	3.84%	96.16%
Process7	102	101	3.66%	96.34%
Process8	101	100	4.10%	95.90%
Process9	100	99	9.76%	90.24%

Table 6: Statistical Report for 6 Workers

Object	Number of Entries	Number of Exits	Relative Empty	Relative Occupation without Interruptions
Process	109	108	0.00%	100.00%
Process1	108	107	0.00%	100.00%
Process2	107	106	0.60%	99.40%
Process3	106	106	1.37%	98.63%
Process4	106	105	1.97%	98.03%
Process5	105	104	2.48%	97.52%
Process6	104	103	3.76%	96.24%
Process7	103	102	3.68%	96.32%
Process8	102	101	3.85%	96.15%
Process9	101	100	9.76%	90.24%

Table 7: Statistical Report for 7 Workers

V. Conclusion

The study highlighted the importance of efficient layout design in improving productivity and reducing operational costs in the manufacturing industry. By transforming the existing cellular batch layout into a linear flow of material, the research aimed to eliminate bottlenecks, reduce waiting time, and enhance overall production efficiency. Through the simulation and analysis conducted using Tecnomatix Plant Simulation, valuable insights were gained regarding the impact of layout design on cycle time reduction.

The software facilitated the identification of inefficiencies, bottlenecks, and opportunities for optimization. It allowed for the evaluation of different scenarios and strategies for improving layout design and resource allocation. The findings of this research demonstrated the significance of optimal layout design and human resource allocation in manufacturing units. By adopting an efficient layout that enables a smooth material flow and minimizing unnecessary movement, manufacturers can achieve significant improvements in productivity, resource utilization, and customer satisfaction. Furthermore, the study emphasized the value of using Tecnomatix Plant Simulation software in the layout optimization process. The software provided a user-friendly interface, enabling the creation of digital models and the simulation of various scenarios. It facilitated data-driven decision-making and supported the continuous improvement efforts of manufacturing organizations.

The research outcomes have practical implications for the manufacturing industry, providing valuable insights into effective layout design strategies and resource allocation techniques. Manufacturers can leverage the findings to make informed decisions and implement optimized layout designs in their facilities. This, in turn, can lead to improved operational efficiency, reduced cycle time, and enhanced overall productivity. Overall, this research paper contributes to the field of industrial engineering by presenting a comprehensive methodology for designing and optimizing layout in a manufacturing unit. The utilization of Tecnomatix Plant Simulation software adds a significant value to the research, providing a powerful tool for simulating and analysing the impact of layout design on cycle time reduction and human resource allocation. The findings and insights presented in this paper can serve as a foundation for further research and practical applications in the manufacturing industry.

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