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Optimizing Ketchup Manufacturing Process: A Tecnomatix Simulation for Reduced Waiting Time and Improve Operational Efficiency

Afeez Olamide Showole, Alexander Osayimwense Osadolor, Tochukwu Judethaddeus Eze, Robertson Ojeka Owulo

Students, School of Computing, Engineering & Digital Technologies,
Sustainable Engineering System, Teesside University, Middlesbrough, UK

Abstract: *This research investigates the optimization of a ketchup production factory layout using Tecnomatix Plant Simulation software to enhance resource utilization and production efficiency. Both push and pull system were used to analyzed the entire ketchup production process, from receiving raw tomatoes to the final product storage, incorporating various processing stations with different processing times. In a push environment, driven by predetermined schedules, the simulation results showed an increasing trend in throughput over 4, 7, 11, and 14 days, with significant efficiency gains over time. In a pull environment, driven by actual customer demand, throughput simulations of 50, 100, 200, and 500 units demonstrated increasing productivity with higher workloads. The findings highlight the importance of optimized workstation layouts to reduce idle time and improve workflow, emphasizing that while push environments maintain consistent productivity, pull environments offer greater efficiency through flexibility and responsiveness to demand.*

Keywords: Ketchup production; Factory layout optimization; Tecnomatix Plant Simulation; Throughput analysis; Bottleneck reduction; Workflow management; Resources Utilization

I. INTRODUCTION

The ketchup production industry is a significant sector within the food processing industry. Ketchup manufacturing involves receiving raw materials, processing them hygienically, packaging the final product, and ensuring quality control throughout the process. Traditional methods of layout design and optimization often rely on trial-and-error approaches, which can be time-consuming and costly. Efficient layout design is crucial for optimizing production flow, minimizing bottlenecks, and maximizing throughput in a production factory [1]. Optimizing production efficiency and layout is essential for maximizing output, minimizing costs, maintaining product quality, and making data-driven decisions based on simulation results.

The Tecnomatix Plant Simulation software is utilized for the modeling and analysis of different layout configurations, evaluating their performance [1], and identifying opportunities for improvement in production facilities, including material flow, resource utilization, and logistics [2]. It empowers its users for the simulation of different production schedules and evaluate their impact on overall productivity, which helps in determining the most efficient production rates and throughput to resource utilization ratio [3]. Tecnomatix Plant Simulation provides tools to create and optimize 3D factory layouts, allowing users to design and configure the layout of the production lines and facilities [4]. This helps in improving resource utilization, throughput, and the overall efficiency of factory operations [2].

Assembly line balancing is a popular method for improving and balancing manufacturing lines in numerous industrial sectors throughout the world. The purpose is to manufacture a high volume of items within shortest time while maintaining optimal productivity, cost-effectiveness and quality. Research indicates that a sewing line in VIP Industries Private Limited at Bangladesh utilised the Ranked Positional Weight Method (RPWM) line balancing approach with Tecnomatix modelling software [5]. The RPWM approach identifies potential for improvement in the sewing line for Duffle Trolley bags and Tecnomatix simulation software evaluates the viability of proposed modifications. By

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eliminating wasted time on the assembly line and maintaining equitable working time at each station, efficiency in manufacturing can be considerable increased.

Optimization of packaging line performance is an important aspect of enhancing productivity in industry. The past experience to improve in production performance on packaging lines has become insufficient. AB Breweries in Nigeria used Tecnomatrix Plant Simulation to improve the design and operation of a complicated beer packaging plant [6]. The simulation model created a 3D visual representation of the system, which improved both efficiency and performance. Measurement of performance is a key consideration. Performance measurement entails comparing manufacturing outputs to running time. This enables AB Breweries to evaluate the efficiency and efficacy of their packaging lines.

One of the leading global developer and producer of packaging machines and comprehensive packaging systems for the confectionery sector LoeschPack GmbH Company which headquartered in Bavaria, Germany utilised Siemens Tecnomatrix plant Simulation for a discrete event simulation tool [7]. The software was used to optimise, validates the planning and commissioning of packaging machinery and systems, as well as improving company understanding of the packaging process. They also use this software to optimise the operations of their manufacturing facilities production lines and specific logistical activities.

Emixa, a firm looking to expand while retaining quality and cost-effectiveness, implemented Tecnomatix plant simulation software to transform their manufacturing process. They employed simulation-driven techniques to optimise processes and achieve incredible efficiency [8]. The software is compatible across desirable plant planning levels within global facilities and local plants for specific production lines.

For design and simulation research shown that logistics planning in Automatic Plant Factory [9],using Tecnomatix Plant Simulation software, research focuses on develop and simulate logistics planning in autonomous plant manufacturing. It investigates how software may be utilised to optimise material flow, layout design and resource allocation in the production, hence increasing efficiency and productivity. However, it emphasises the advantages of utilising simulation models to analyse and enhance material handling, transportation, and storage operations in order to reduce costs while increasing throughput.

Mining transportation by train is critical for transporting excavated materials to processing facilities. For mining rail transport to work properly, operational indicators must be monitored on a regular basis. Computer simulation tools can be used with traditional analytical tools that utilise mathematical and statistical methodologies. Mining rail transport may benefit from many computer design and simulation technologies for efficient operation and analysis. Research describes how the Tecnomatix Plant Simulation was used to develop and simulate mining rail transport [10]. The software is designed for manufacturing, however been used for building complicated visualisations and complex processes of mining rail transport.

Current ketchup production processes are often hampered by inefficiencies in factory layout, leading to issues such as: delays in material flow between processing stages which can significantly impact production time, inefficient equipment placement and worker allocation that can lead to underutilization of resources. These inefficiencies can lead to inefficiencies in material flow, bottlenecks in production processes, decreased throughput and ultimately increased production costs. This study was aimed at the design and simulation of a layout of a ketchup production factory employing the use of Tecnomatix Plant Simulation software to enhance resource utilization and optimize production schedules. This work entailed the use of Tecnomatix Plant Simulation software to build a digital model of a ketchup production factory, simulate the entire factory layout of the process of the production of ketchup, from receiving the raw tomatoes to the finished product storage.

II. METHODOLOGY

The primary objective is to establish a ketchup processing facility with a defined production capacity to meet market demand. This involves determining the volume of ketchup to be produced within a specified timeframe, such as daily, weekly, or monthly targets. Also, to improve operational efficiency by optimizing production processes, minimizing waste, and reducing downtime.

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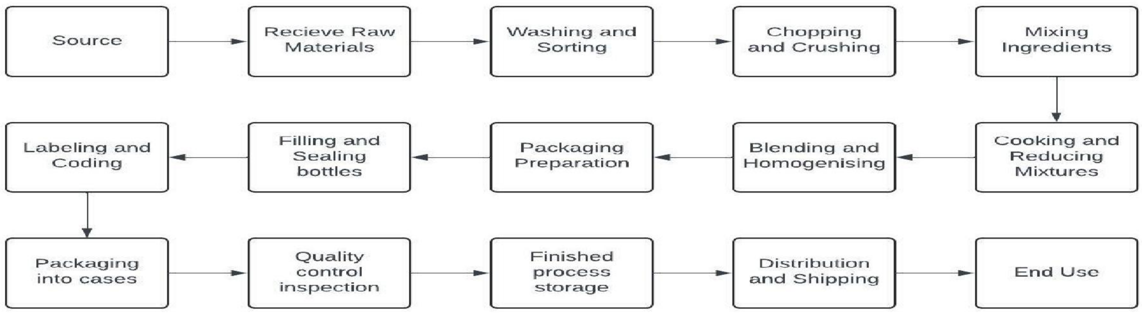

Figure 1. Chart of product flow

This work considered the ketchup production factory from washing and sorting to quality control inspection, of which there were 10 plausible stations to achieve automation of this process as shown in figure 1, and the most common practices are a single straight line factory layout. Due to the fact that all the stations do not have the same processing time and some stations will demand way more time than some other stations, it will be inevitable to encounter stations with a high working time, waiting time or blocked percentages as opposed to others, therefore the addition of other stations were crucial to optimize the flow of the product to achieve a high efficiency and boost production.

The processes of washing and sorting were allotted a station, as well as the process of chopping and crushing. 4 stations were used to represent both processes, and this model incorporates the use of 2 turn-tables; with 1 turn-table to serve the 2 conveyor belts ferrying products from the washing and sorting stations to 2 conveyor belts per 1 turn-table to the chopping and crushing stations because, on the account of human input, as there can be a lag in either of the washing and sorting stations, and so the turn-table is present to send forth the readily available batch on to the next phase.

After the chopping and crushing phase, there are 2 turn-tables; with 1 turn-table to serve the 2 conveyor belts ferrying products from the chopping and crushing stations, and the 2 turn-tables individually supply 1 conveyor belt each to arrive at a total of 2 stations for mixing ingredients. The turn-tables are there to ensure a reduction in time, thereby conveying the next available batch of products to the next phase. Each station at the process of ingredients mixing supplies 2 conveyor belts, which gave 4 stations for the cooking, and 2 of each of the cooking stations conveyed to 1 station for the blending and homogenizing. The 2 stations for the blending and homogenizing convey products to converge at 1 station for the packaging, and it is a singular layout of stations all the way to the quality control inspection. Figure 2 shows the top view of the factory layout, figure 3 shows the 3-Dimensional view of the factory layoutand table 1 shows the definition of the labeled station functions.

Table 1. Table of stations and their processing time

Functions	Stations	Processing Time (minutes)
Washing and Sorting	MU121	45
	MU131	
	MU12	
	MU13	
Chopping and Crushing	MU221	45
	MU231	
	MU22	
	MU23	
Mixing Ingredients	MU311	30
	MU31	
Cooking and Reducing Mixtures	MU421	90
	MU431	

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	MU42	
	MU43	
Blending and Homogenizing	MU511	30
	MU51	
Packaging Preparation	MU6	30
Filling and Sealing Bottles	MU7	30
Labelling and Coding	MU8	20
Packaging into Cases	MU9	20
Quality Control Inspection	MU10	30

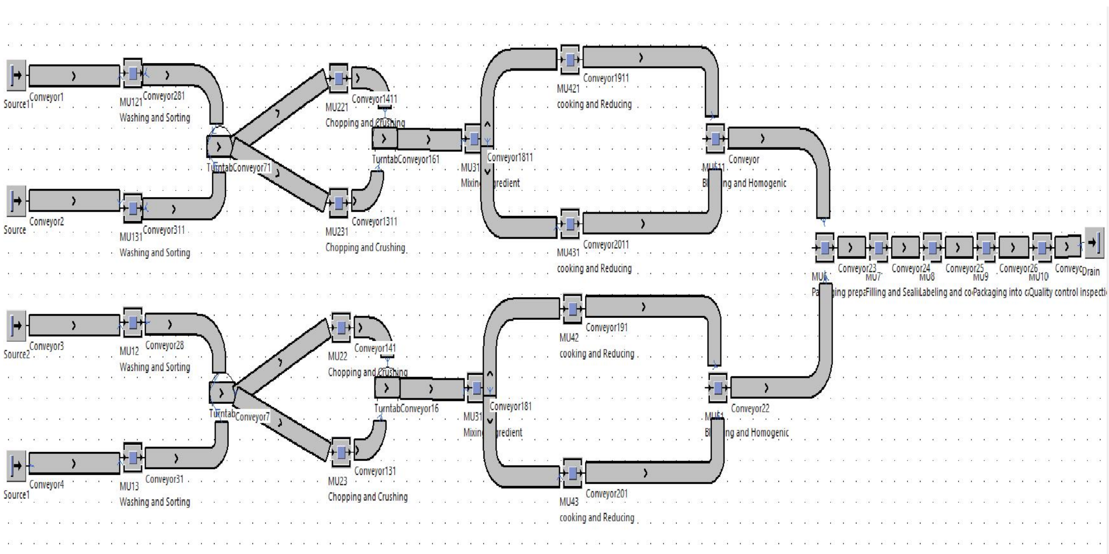

Figure 2. 2D view of the designed factory layout

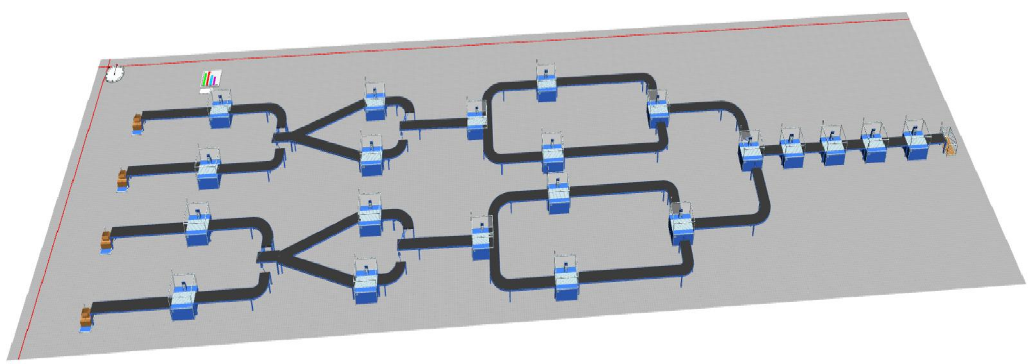

Figure 3. 3D view of the designed factory layout

III. RESULT AND DISCUSSION

The arrangements of the workstations in this work are in anoptimal sequence to facilitate smooth workflow and minimize idle time between process steps for the consideration of a push and pull environment, no matter the factory size.

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Push Environment

For a push environment, where the ketchup production is driven by forecasts and predetermined schedules rather than actual customer demand, the optimal layout of this ketchup production factory simulates instances for 4 days, 7 days, 11 days and 14 days.

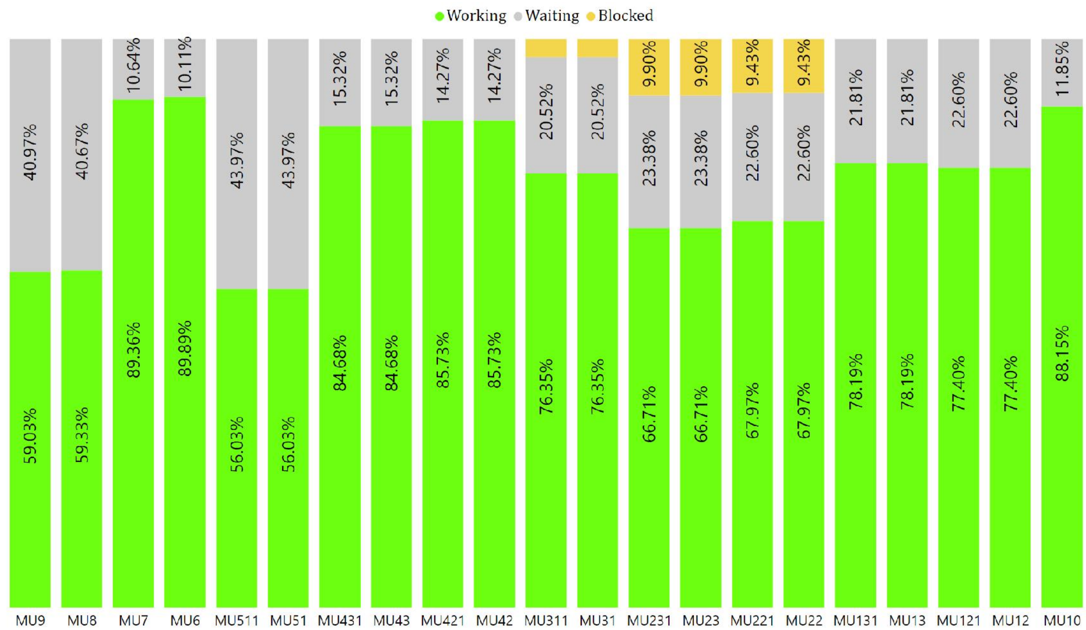

Figure 4. Resource statistics for 4 days

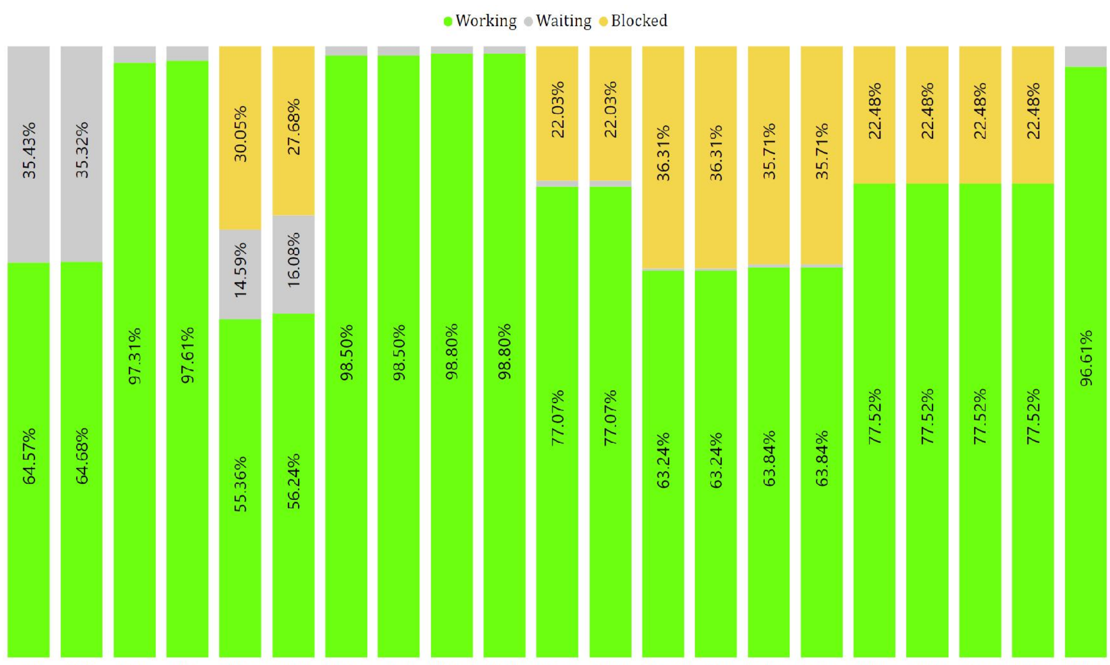

Figure 5. Resource statistics for 7 days

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Figure 6. Resource statistics for 11 days

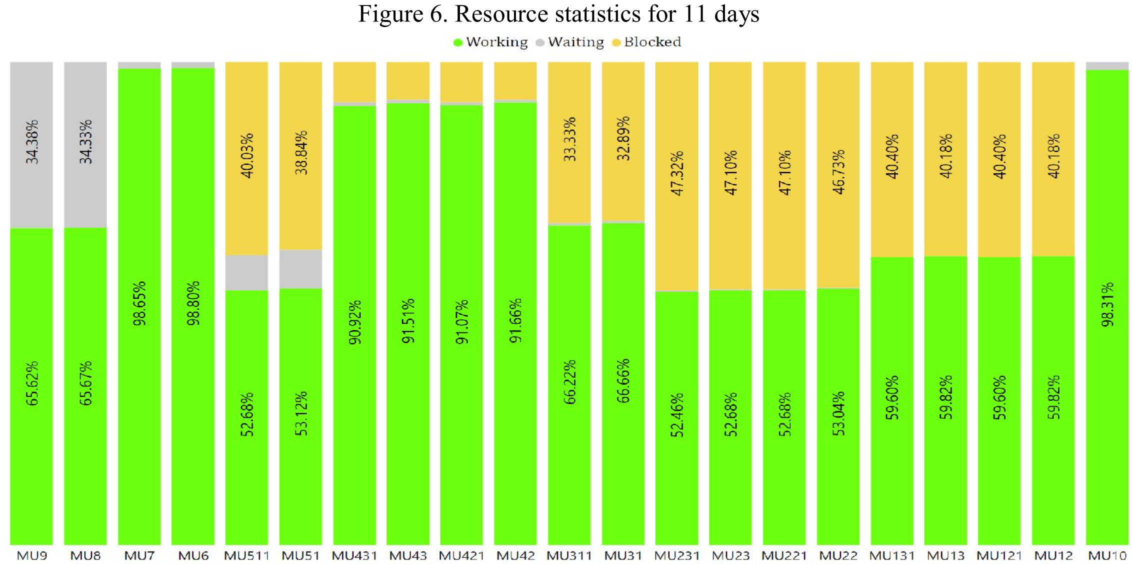

Figure 7. Resource statistics for 14 days

Table 2. Table of resource statistics for pushing for 4, 7, 11 and 14 days

Days Working	Throughput	Units per hour	Units per day
4	169	1.76	42.25
7	324	1.93	46.29
11	516	1.95	46.91
14	660	1.96	47.14

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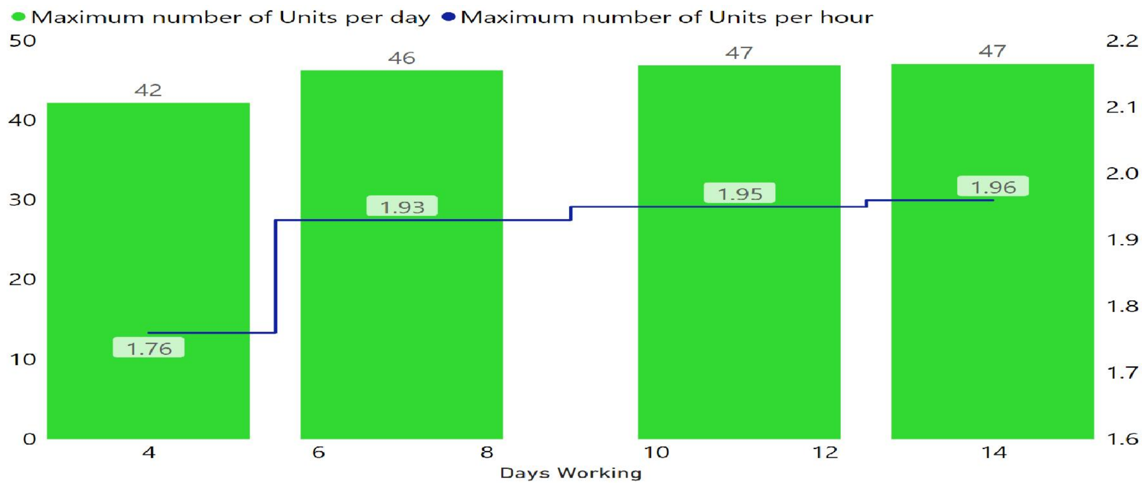

Figure 8. Chart of analysis from 4 days to 14 days

From figure 8, the data shows a general upward trend in throughput over the days of production from 4 days to 14 days. The throughput units per hour and per day show a steep increase from 4 days of production to 7 days of production, while it shows a slight increase from 7 days to 14 days of production, this indicates that the production process becomes more efficient in terms of hourly output as it continues operating, and also that the production process shows an improvement in production efficiency over time.

Pull Environment

In a pull environment, production is driven by actual customer demand, which triggers the production of goods as needed. The optimal layout of this work of a ketchup production factory in a pull environment gives the required focus on flexibility to achieve a high efficiency for throughputs of 50, 100, 200 and 500.

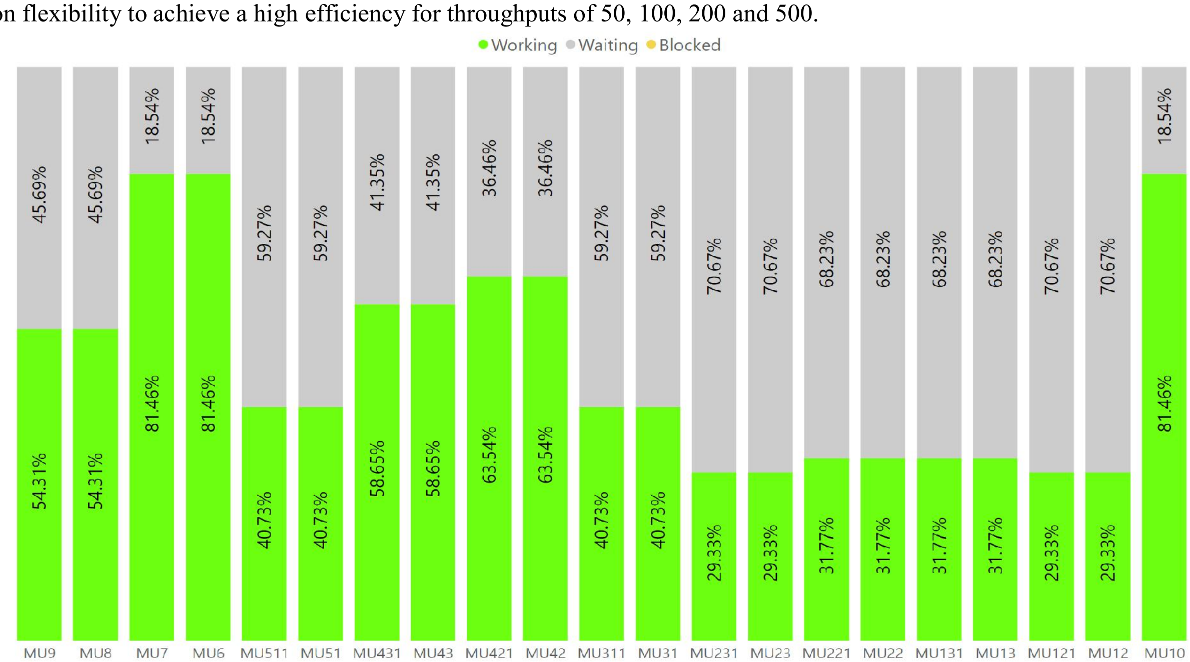

Figure 9. Resource statistics for throughput of 50 units

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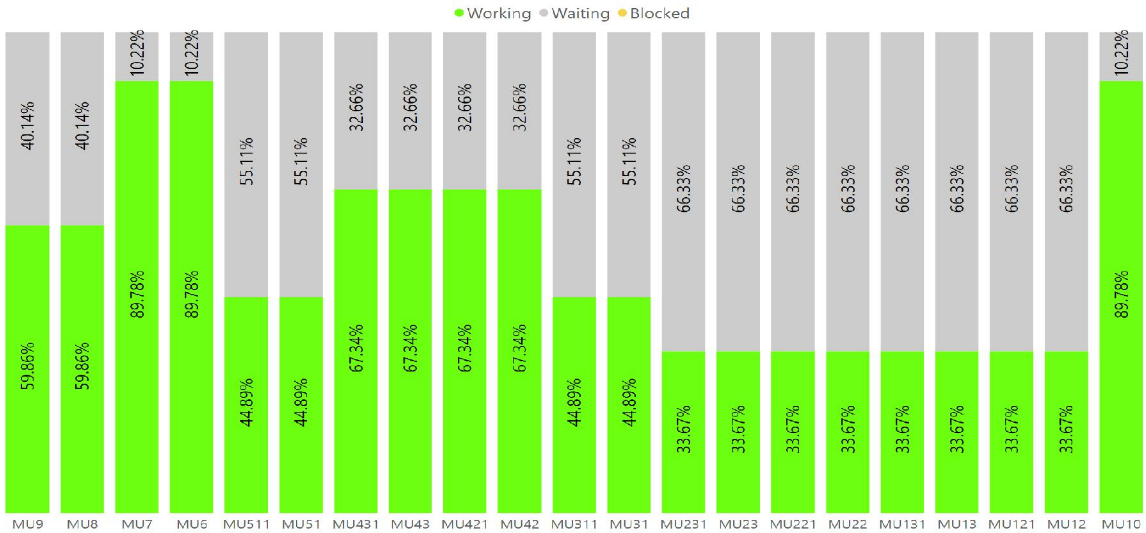

Figure 10. Resource statistics for throughput of 100 units

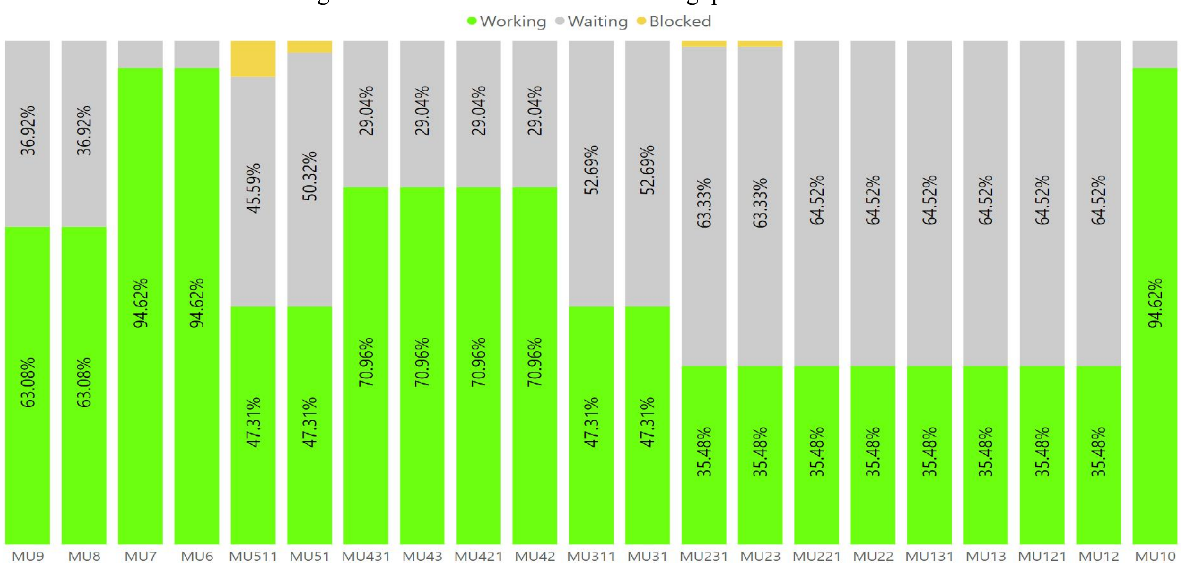

Figure 11. Resource statistics for throughput of 200 units

Table 3. Table of resource statistics for pulling a throughput of 50, 100, 200 and 500 units

Throughput	Units per hour	Units per day
50	1.63	39.1
100	1.8	43.1
200	1.89	45.42
500	1.96	46.93

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Figure 12. Resource statistics for throughput of 500 units

Table 3 shows the daily and hourly units of the throughputs from 50 to 500 which were then visualized using Power BI, and figure 9, figure 10, figure 11 and figure 12 shows that when the total throughput is less than a hundred, there is a seamless flow of the product from washing and sorting to quality control inspection without the products being piled up in wait at any of the stations, this also means that there are more stations experiencing more waiting times. So also, when the throughput is from an average of 200, there will be products piled up in wait at certain stations, but the number of waiting time of all stations reduces and the number of working times of the stations increases, which indicates an increase in efficiency with an increase in throughput.

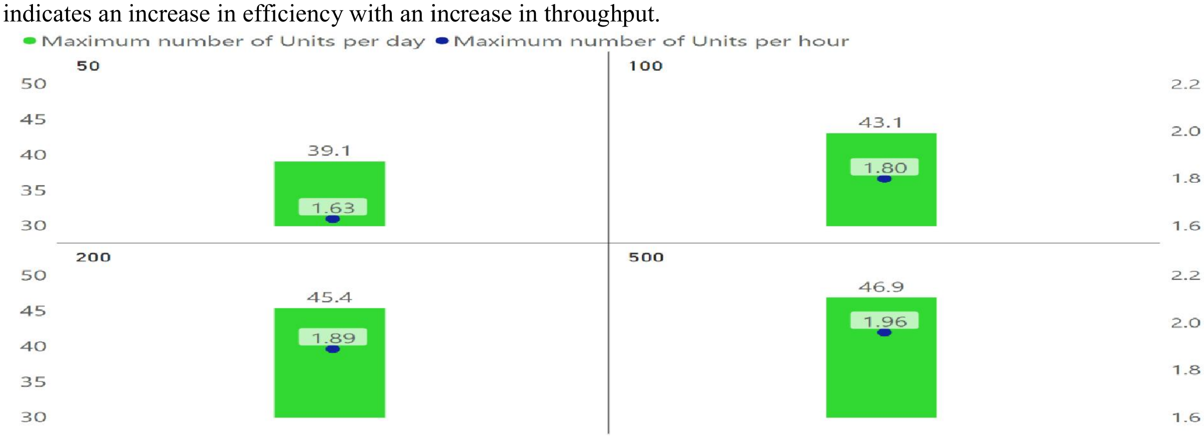

Figure 13. Chart of analysis for throughputs of 50, 100, 200 and 500

Figure 13shows that the units per hour demonstrate an increasing trend as throughput increases. This indicates that the production process becomes more productive on an hourly basis as throughput rises, and it also indicates that the production process achieves higher daily production rates as throughput increases.

Figure 8 and figure 13 show that the number of stations with a higher number of stations that have higher number of working times are experienced when there is a constant flow of the product in the push environment, but the average yield per hour is slightly higher in the pull environment.

IV. CONCLUSION

The research study demonstrates clearly how the layout of workstations affects the efficiency of ketchup production in both push and pull environments. Under the push environment, which was governed by predetermined schedules and forecasts, the simulation results for the following days (4, 7, 11, and 14 days) revealed a distinct increasing pattern in throughput. More specifically, there was a substantial increase in units per hour and units per day from day fourto dayseven, followed by a gradual improvement from day seven to dayfourteen. This implies that as the production process continues to operate, its efficiency increases, leading to greater production efficiency with sustained operations.

On the other hand, within the pull environment, which is influenced by real-time customer demand, the system's adaptability and effectiveness were underscored through simulations of throughputs of 50, 100, 200, and 500 units. There was a consistent and uninterrupted flow of products with minimal waiting periods at each station when the throughput was below 100 units. Nevertheless, as the throughput surpassed 200 units, an accumulation of products occurred at specific stations; also the overall efficacy witnessed an improvement. The increase in daily and unit-per-hour production rates indicates that as duties increase, the production process becomes more efficient.

When compared to the pull environment, the push environment showed a marginally higher average yield per hour and longer working periods for a greater number of stations as a result of the constant flow of products. This suggests that although a push environment can sustain a consistent workflow, a pull environment can optimise efficiency by adjusting to actual demand.

The results emphasise the significance of efficient workstation layouts in improving the performance of production. In push environments, increased productivity can result from a consistent operation period; on the other hand, in pull environments, improved productivity can be substantially increased through flexibility and responsiveness to demand.

The findings of this research offer significant contributions to the optimisation of production processes, regardless of whether the emphasis is on demand-driven or forecast-driven operations. By utilising these innovations, manufacturing companies can enhance their workflow management, minimise waiting periods, and ultimately attain increased levels of production efficiency.

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