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Process Improvement Methodology: A Research Study of Process Improvement of Peppermint Tailoring via the Use of Operations Research

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ABSTRACT

Low-volume manufacturing presents distinct operational challenges, including inefficiencies and production delays that can hinder productivity and limit output. This study investigates the manufacturing process of Peppermint Tailoring, a company engaged in low-volume T-shirt production, to identify and address inefficiencies using operations research and industrial engineering tools. Despite the prevalence of low-volume enterprises, literature addressing tailored process improvement strategies for such contexts remains limited. The research adopted a descriptive quantitative design, integrated with a case study approach. Key methodologies included time-and-motion studies, Fishbone Diagrams, and discrete-event simulation via ProModel. Data collection focused on measuring standard and actual task times to calculate production efficiency and assess resource utilization. Two alternative facility layouts were proposed and evaluated through simulation modeling. The initial production efficiency of Peppermint Tailoring was recorded at 73.08%. Following the implementation of the first proposed layout, efficiency rose significantly to 89.23%, while the second alternative achieved an 84.62% efficiency rate. The improvements were primarily attributed to strategic reallocation of worker tasks and redesigning the facility layout, which led to reduced idle time and enhanced workflow. Simulation outputs confirmed increased utilization rates and shortened task completion times. The study concludes that suboptimal facility arrangements and task allocations were the main contributors to production inefficiencies. The implemented interventions resulted in substantial improvements, validating the applicability of operations research and industrial engineering techniques in low-volume settings. The researchers recommend continuous monitoring, iterative facility layout evaluation, and worker-centered process enhancements to maintain and further improve operational efficiency.

RESUMO

A manufatura de baixo volume apresenta desafios operacionais distintos, incluindo ineficiências e atrasos na produção que podem prejudicar a produtividade e limitar o volume de saída. Este estudo investiga o processo de manufatura da Peppermint Tailoring, uma empresa dedicada à produção de camisetas em baixo volume, para identificar e solucionar ineficiências utilizando ferramentas de pesquisa operacional e engenharia industrial. Apesar da prevalência de empresas que operam com baixo volume, a literatura que aborda estratégias de melhoria de processos específicas para tais contextos permanece limitada. A pesquisa adotou um delineamento quantitativo descritivo, integrado a uma abordagem de estudo de caso. As principais metodologias incluíram estudos de tempos e movimentos, diagramas de Ishikawa (espinha de peixe) e simulação de eventos discretos utilizando o software ProModel. A coleta de dados concentrou-se na medição dos tempos padrão e reais das tarefas para calcular a eficiência da produção e avaliar a utilização de recursos. Dois layouts alternativos para as instalações foram propostos e avaliados por meio de modelagem de simulação. A eficiência inicial de produção da Peppermint Tailoring foi registrada em 73,08%. Após a implementação do primeiro layout proposto, a eficiência aumentou significativamente para 89,23%, enquanto a segunda alternativa alcançou uma taxa de eficiência de 84,62%. As melhorias foram atribuídas principalmente à realocação estratégica das tarefas dos trabalhadores e ao redesenho do layout das instalações, o que resultou na redução do tempo ocioso e na otimização do fluxo de trabalho. Os resultados da simulação confirmaram o aumento das taxas de utilização e a redução dos tempos de conclusão das tarefas. O estudo conclui que arranjos de instalações e alocações de tarefas subótimos foram os principais fatores que contribuíram para as ineficiências de produção. As intervenções implementadas resultaram em melhorias substanciais, validando a aplicabilidade de técnicas de pesquisa operacional e engenharia industrial em ambientes de baixo volume. Os pesquisadores recomendam o monitoramento contínuo, a avaliação iterativa do layout das instalações e a implementação de melhorias nos processos centradas nos trabalhadores, visando manter e aprimorar ainda mais a eficiência operacional.

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Introduction

Improvement and facilitation of the product introduction process in low-volume manufacturing industries required tailored solutions specific to their operational contexts (Afonso et al., 2018; Narayanamurthy & Gurumurthy, 2016). These needs, often associated with distinct product characteristics and production systems, stemmed from the fundamental differences between low-volume and high-volume manufacturing environments. Consequently, it was crucial to differentiate between these manufacturing types by highlighting their respective operational features. Understanding how these distinctions affected the product introduction process allowed for more effective and efficient improvement strategies within low-volume firms. This understanding enabled the development of specialized approaches to streamline the product introduction process and address delays.

Recent studies have indicated a persistent gap in literature focused on the product introduction process in low-volume manufacturing industries (Zhan et al., 2021; Afonso et al., 2018). These findings emphasized the need to investigate how the unique traits of such industries influenced their production systems and how improvements could be aligned with those influences. The present study aimed to apply Industrial Engineering methodologies to mitigate production delays and improve operational efficiency at Peppermint Tailoring. A time and motion study were employed to calculate each worker's standard time, basic time, and allowance factor. Interviews with production staff were conducted to identify the root causes of inefficiencies.

This study aims to apply Industrial Engineering methodologies to mitigate production delays and improve operational efficiency at Peppermint Tailoring.

Based on the identified operational inefficiencies and workplace concerns at Peppermint Tailoring, the study aims to address the following research questions:

RQ1: What factors contribute to the low production efficiency rate (73.08%) observed in the current manufacturing system of Peppermint Tailoring?

RQ2: How does the current facility layout affect the utilization of workstations, particularly those recorded with 0% usage such as the Box and Curing Stations?

RQ3: To what extent does the allocation of tasks among production stations influence workload imbalance and resource underutilization?

RQ4: How does excessive movement and blocking of raw materials (82.10% move logic time; 21+ minutes blocked) affect the overall efficiency and flow of the production line?

RQ5: What is the impact of current ergonomic conditions and lack of safety protocols on worker productivity and job satisfaction?

RQ6: How responsive is management to operational concerns raised by workers, and how does this affect day-to-day production activities?

RQ7: In what ways do inadequate ventilation and environmental conditions affect the physical and mental well-being of employees?

RQ8: What are the potential health risks associated with the absence of safety measures for workers in high-heat and pressure-intensive areas of production?

Methodological Procedures

This research adopted a descriptive quantitative research design integrated with a case study approach to systematically investigate and improve the production process of Peppermint Tailoring, a low-volume T-shirt manufacturing firm. The selected methodology was appropriate for addressing the study's primary objective: identifying the causes of production inefficiencies and evaluating strategic interventions through empirical and data-driven means.

Research Design

Descriptive quantitative research, as defined by Creswell and Creswell (2018), involves the systematic collection of quantifiable information that accurately characterizes current conditions or phenomena. This approach facilitated the structured assessment of the production system, allowing for detailed measurement of operational variables such as task durations, workstation utilization, and production output.

Complementing the quantitative approach, a single-case study method was employed to explore the research problem within its real-world context (Yin, 2018; Ridder, 2017). Given the study's emphasis on understanding the interplay of multiple variables in a live production environment, the case study framework enabled a holistic and contextual analysis of the unique challenges faced by low-volume manufacturers.

Data Collection Procedures

Time-and-Motion Study

The researchers conducted a comprehensive time study across all workstations to measure the standard time, observed time (using the Flyback Timing method), and transportation time for each production task. This data provided the foundation for calculating baseline efficiency, identifying bottlenecks, and evaluating idle or underutilized stations.

Fishbone Diagram (Ishikawa Tool)

A cause-and-effect diagram was constructed to categorize potential root causes of inefficiencies into major categories, including Manpower, Methods, Machines, Materials, and Environment. This qualitative tool provided a visual synthesis of systemic issues affecting production performance (Alghamdi & Abu-Mahfouz, 2020).

Simulation Modeling (ProModel Software)

To test alternative layouts and production strategies, discrete-event simulations were developed using ProModel. Two proposed facility layouts were simulated to evaluate their effectiveness in enhancing efficiency, reducing bottlenecks, and minimizing non-value-adding activities. Simulation outputs included:

- Workstation utilization rates
- Processing and movement times
- Resource capacity levels
- System flow behavior and entity congestion

Data Analysis

Descriptive Analysis

Standard statistical techniques (means, percentages, utilization rates) were used to quantify operational performance. Production efficiency was computed using the formula:

$$\text{Production Efficiency (\%)} = \left(\frac{\text{Actual Output Rate}}{\text{Standard Output Rate}}\right) \times 100$$

Comparative Simulation Analysis

Simulations results were compared across the current layout and two proposed alternatives. The first layout yielded an efficiency improvement to 89.23%, while the second reached 84.62%. Data were analyzed based on: Average task completion times; Percentage of time spent moving logic, operation, waiting, and blocking; Entity flow patterns and system throughput; Storage congestion and workstation idle times

By combining quantitative data collection, qualitative insight, and predictive simulation, the methodology provided a comprehensive framework for analyzing and improving the operations of Peppermint Tailoring. The approach is particularly applicable to other low-volume manufacturing firms facing similar challenges in process efficiency and resource utilization.

Development

Literature Review

Low-volume manufacturing presents distinct challenges such as inconsistent workloads, underutilized resources, and inefficient workflows. Afonso et al. (2018) emphasize that traditional high-volume strategies are often unsuitable for small-scale producers, who require flexible and customized process improvement approaches.

Time-and-motion studies remain a foundational tool in identifying inefficiencies by measuring actual task durations and idle times (Heizer, Render, & Munson, 2016). Paired with Fishbone Diagrams, these tools help isolate root causes across manpower, methods, machinery, materials, and environment (Alghamdi & Abu-Mahfouz, 2020). Simulation modeling, particularly using tools like ProModel, enables manufacturers to evaluate proposed changes without disrupting actual operations (Russell & Taylor, 2017).

Beyond technical improvements, ergonomic conditions and workplace design play a crucial role. Poor ventilation, heat, and limited workspace reduce productivity and increase health risks (Zhan et al., 2021). Worker feedback and management responsiveness are also essential in ensuring sustainable change, as participative improvement strategies help align processes with frontline realities (Ridder, 2017).

This study builds on these frameworks by applying industrial engineering methods and simulation to improve the efficiency and safety of Peppermint Tailoring's production system.

Results and Discussion

The researcher proposed their solution into three alternatives based on its data analysis. The proposed action will serve as a recommendation for the improvement of the process of the firm, considering those factors and the possible risk of accepting those alternatives. In addition, those risks are identifiable and will provide an efficient solution to lessen the effect of chance.

For its alternative, the researcher intends to focus on existing data by providing comprehensive-time study data and its existing pro model data.

For the Time study, the researcher provides the standard time and its observed time (Flyback Timing) for its comprehensive analysis, which will be used for the interpretation of pro-model, which will be used for creating alternatives for the company.

Table 1.

Standard Time of manufacturing Dress

Process Station	Operation Time (mins.)	Transportation (mins.)
Box	0	0.0833
Curing Station	3	1
Cutting Station	5	0.78
Packing	0.5	0.55
Bin	0	0.15
Printer	5	0.583
Finish End	1	0
Total	15.6463	

Source: Standard time study data

The time study for manufacturing a dress reveals a total standard time of 15.6463 minutes, comprising 15.5 minutes of operation time and 3.1463 minutes of transportation time. Key inefficiencies include significant transportation times at the curing (1 minute) and cutting (0.78 minutes) stations, while bottlenecks are observed at the cutting and printer stations, each requiring 5 minutes of operation. Idle stations like the box and bin contribute transportation time without direct operations, suggesting opportunities for streamlining. To enhance efficiency, recommendations include optimizing material handling, reducing transportation times, addressing bottlenecks through automation or task parallelization, and reassessing the necessity of idle stations. Simulation modeling using Pro-Model is proposed to evaluate alternative lay- outs and workflows for improving the manufacturing process.

Table 2.

Observe Time (Flyback Timing)

Process Station	OT1	OT2	OT3	Average OT
Box	0.122	0.182	0.257	0.187
Curing Station	4.325	4.969	4.581	4.625
Cutting Station	6.583	7.865	8.301	7.583
Packing	0.7941	0.9256	0.8873	0.869
Bin	0.0272	0.0224	0.0263	0.0253

Source: Researcher's own elaboration, 2025.

After the TMS (Time and Motion Study), the Researcher computes the Production Efficiency by determining the actual output rate of the product and the standard output rate used in the company. The expected output rate helps the research- er determine the efficiency of the existing production layout. With the help of the work-study method, a worker's job process is decided. Based on computation, the existing production efficiency is about 73.08%.

Production efficiency = (actual output rate / standard out- put rate) x 100% Actual output rate = 475 T-Shirts/8 hours =59.375 T-shirts/hour Standard output rate = 650 T-Shirts/8 hours = 81.25 T-shirts/hour Efficiency % = (59.375/81.25) x 100% = 73.08%.

The researcher proposed a new and improved facility layout to increase their output and eliminate delays in the manufacturing facility. The management should implement the new process to increase efficiency and the number of outputs produced daily. Moreover, there are areas of concern regarding materials, tools, and supplies in T-shirt production.

Figure 1.

Existing Production Layout of the T-Shirt Manufacturing Process

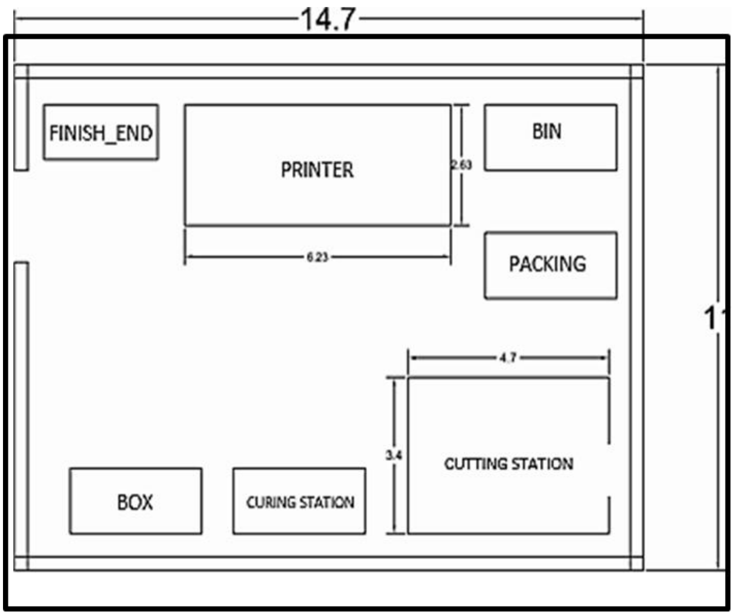

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Table 3.

Results of 1st proposed simulation

Name	Scheduled Time (HR)	Capacity	Total Entries	Avg Time per Entry (MIN)	Avg Contents	Maximum Contents	Current Contents	% Utilization
Box	8.00	999999.00	150.00	0.00	0.00	1.00	0.00	0.00
Curing Station	8.00	150.00	150.00	0.00	0.00	1.00	0.00	0.00
Cutting Station	8.00	150.00	150.00	43.71	13.66	100.00	0.00	9.11
Bin	8.00	999999.00	600.00	93.17	116.50	331.00	0.00	0.01
Printer	8.00	150.00	750.00	3.00	4.69	9.00	0.00	3.13
Packing	8.00	150.00	150.00	64.35	20.11	83.00	0.00	13.41
Finish End	8.00	150.00	750.00	2.04	3.20	7.00	0.00	2.13

Source: Researcher's simulation data using ProModel, 2025.

The first proposed simulation revealed notable inefficiencies in resource utilization across the production process. Key stations such as the Box and Curing Station remained idle with 0% utilization, indicating poor integration into the workflow. While the Cutting, Printer, and Finish End stations processed a high number of entries, their utilization rates remained low, ranging from 2.13% to 9.11%, suggesting imbalances in workload distribution. The Packing Station demonstrated the highest utilization at 13.41%, highlighting its more active role in the system. Overall, the simulation emphasized the need for better synchronization and workload realignment among stations to improve production flow and operational efficiency (Stevenson, 2020; Heizer et al., 2016; Russell & Taylor, 2017).

Table 4.

Pro model simulation result data.

Name	Scheduled Time (HR)	% Empty	%Part Occupied	% Full	% Down
Box	8.00	100.00	0.00	0.00	0.00
Curing Station	8.00	100.00	0.00	0.00	0.00
Cutting Station	8.00	72.04	27.96	0.00	0.00
Bin	8.00	16.95	83.05	0.00	0.00
Printer	8.00	18.90	81.10	0.00	0.00
Packing	8.00	47.96	52.04	0.00	0.00
Finish End	8.00	19.40	80.60	0.00	0.00

Source: ProModel simulation data

The analysis of Table 4 revealed that several workstations in the simulated production system were either underutilized or overutilized. Both the Box and Curing Stations remained entirely idle during the entire 8-hour schedule, with 100% empty time, indicating inefficiencies or unnecessary inclusion in the process (Heizer, Render, & Munson, 2016; Russell & Taylor, 2017).

The Cutting Station had low utilization, being part-occupied only 27.96% of the time, suggesting it was not a significant contributor to the production bottleneck. On the other hand, the Bin, Printer, and Finish End stations operated at high efficiency, with part-occupied times of 83.05%, 81.10%, and 80.60% respectively, showing they handled a substantial portion of the workload. The Packing Station also showed moderate activity, being part-occupied 52.04% of the time. These results suggested that the production line had imbalances in resource deployment, where some stations were overburdened while others remained idle, highlighting the need for better process flow and workload distribution.

Table 5.

Running time

Name	% In Move Logic	%Waiting	%In Operation	%Blocked
Raw Material	82.10	0.55	5.02	12.33

Source: Running Time

The analysis of Table 5 demonstrated that raw materials in the simulation spent a significant portion of time, 82.10%, in move logic, indicating extensive transportation or movement activities within the system (Heizer, Render, & Munson, 2016; Russell & Taylor, 2017). Only 5.02% of the time was allocated to actual operation or processing, while 12.33% of the time the materials were blocked, implying that production delays occurred due to downstream constraints or unavailable resources. Waiting time was minimal at 0.55%, suggesting that raw materials rarely experienced idle time due to scheduling or resource allocation issues. These results suggested inefficiencies in layout or material handling systems and emphasized the need to streamline internal logistics to improve production flow and reduce time wasted in non-value-adding movements.

Table 6.

Entity activity data

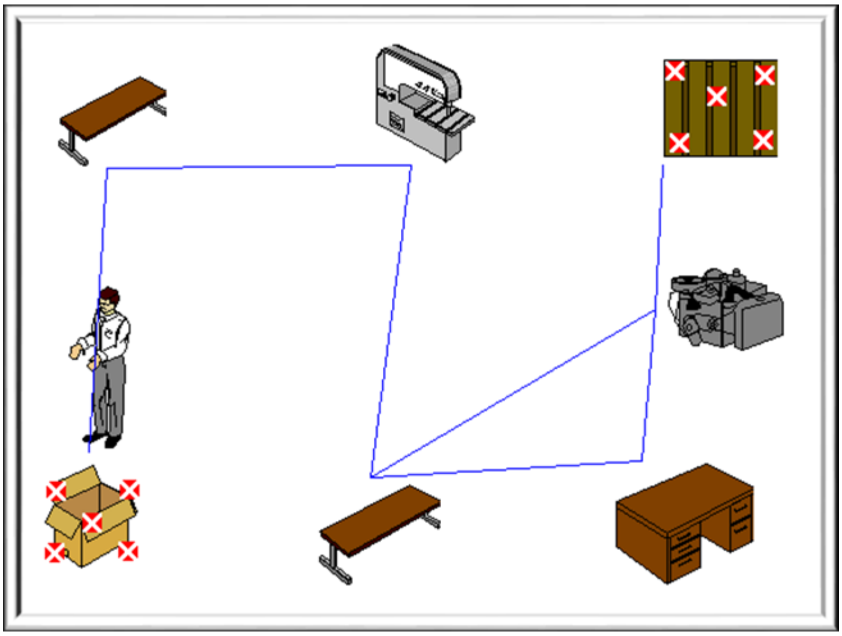
Name	Total Exits	Current Qty in System	Avg Time in System (MIN)	Avg Time in Move Logic (MIN)	Avg Time Waiting (MIN)	Avg Time in Operation (MIN)	Avg Time Blocked (Min)
Raw Material	580.00	170.00	205.51	173.49	1.29	9.50	21.23

Source: ProModel simulation output

The analysis of Table 6 showed that a total of 580 raw material entities exited the system, while 170 units remained within the process flow. Each raw material spent an average of 205.51 minutes in the system, with the majority of that time, approximately 173.49 minutes, dedicated to move logic, indicating extensive transportation or transfer durations (Heizer, Render, & Munson, 2016; Russell & Taylor, 2017). The average waiting time was minimal at 1.29 minutes, and the actual processing time (operation) accounted for 9.50 minutes. Notably, materials experienced an average of 21.23 minutes being blocked, which indicated process interruptions due to downstream unavailability or system constraints. These findings revealed a system where material handling consumed a disproportionate amount of time compared to processing, signaling the need for layout optimization and improved flow management to enhance overall operational efficiency.

Figure 2.

Alternative proposed layout (A higher resolution/colour version of this figure is available in the electronic copy of the article)



The first alternative proposed simulation in figure 2 demonstrated a slightly lower increase in output compared to the initial simulation; however, it still resulted in a more optimized production plan than the current operational system. The data presented in the simulation table showed the machine running time utilized during the second proposed production program, highlighting improved allocation of resources. In addition, the data reflected the percentage of product completion under this alternative, as well as the number of finished products exiting the existing production area.

In terms of production efficiency, the output was calculated using the standard formula: production efficiency = (actual output rate / standard output rate) × 100% (Heizer et al., 2016). The second proposed simulation achieved an actual output rate of 550 T-shirts over an 8-hour period, equivalent to 68.75 T-shirts per hour. When compared to the standard output rate of 650 T-shirts within the same time frame (81.25 T-shirts per hour), the resulting efficiency was 84.62%. This indicated a significant improvement over the current setup, albeit slightly below the optimal benchmark, and suggested a potential for further enhancements in resource utilization and process flow (Russell & Taylor, 2017).

Table 7.

Pro Model data

Name	Scheduled Time (HR)	Capacity	Total Entries	Avg Time per Entry (MIN)	Avg Contents	Maximum Contents	Current Contents	% Utilization
Box	8.00	999999.00	150.00	0.00	0.00	1.00	0.00	0.00
Curing Station	8.00	150.00	150.00	0.00	0.00	1.00	0.00	0.00
Cutting Station	8.00	150.00	150.00	52.07	16.27	86.00	0.00	10.85
Bin	8.00	150.00	150.00	125.12	39.10	91.00	2.00	26.07
Printer	8.00	150.00	593.00	50.93	62.92	150.00	83.00	41.94
Packing	8.00	150.00	660.00	2.99	4.11	16.00	6.00	2.74
Finish End	8.00	150.00	653.00	2.10	2.86	10.00	3.00	1.90

Source: Pro Model data.

The Pro Model simulation data in Table 7 revealed significant variations in activity and utilization across the system components. The Box and Curing Station recorded zero utilization despite their scheduled time of 8 hours and a high-capacity setting, suggesting these resources were either unnecessary or improperly integrated in the model. In contrast, the Cutting Station showed moderate usage with 10.85% utilization, handling 150 entries with an average of 52.07 minutes per entry and a peak content of 86 entities. The Bin exhibited higher utilization at 26.07%, with an average of 125.12 minutes per entry, reflecting storage congestion.

The Printer had the highest activity, with 593 entries and 41.94% utilization, suggesting a major processing hub, although it may be nearing a capacity bottleneck with 83 current contents out of 150 maximum. Conversely, Packing and Finish End stations had lower utilization (2.74% and 1.90%, respectively), processing entries quickly, as shown by their short average time per entry (2.99 and 2.10 minutes). These patterns indicated potential inefficiencies, especially upstream in storage and printing, highlighting opportunities for balancing workload and redistributing system capacity (Heizer, Render, & Munson, 2016; Russell & Taylor, 2017).

Table 8.

Running time of simulation

Name	Scheduled Time (HR)	% Empty	% Part Occupied	% Full	% Down
Box	8.00	100.00	0.00	0.00	0.00
Curing Station	8.00	100.00	0.00	0.00	0.00
Cutting Station	8.00	64.34	35.66	0.00	0.00
Packing	8.00	13.89	86.11	0.00	0.00
Bin	8.00	18.07	80.87	1.06	0.00
Printer	8.00	34.38	65.62	0.00	0.00
Finish End	8.00	31.80	68.20	0.00	0.00

Source: ProModel simulation output

Table 8 illustrated the resource utilization and occupancy levels during the 8-hour simulation period. The Box and Curing Station remained completely empty (100% empty time), indicating they were idle and not integrated into the actual production flow. In contrast, the Cutting Station was utilized more, with 35.66% of the time being partially occupied, while the remaining time (64.34%) it was idle. The Packing station showed high utilization, being 86.11% partially occupied, indicating it played a critical role in the process flow. The Bin was notably active, spending 80.87% of the time partially occupied and even 1.06% fully occupied, suggesting a temporary storage congestion issue. Both the Printer and Finish End stations showed moderate to high utilization, with 65.62% and 68.20% partial occupancy, respectively, pointing to their importance in the workflow. These findings suggested that while some resources were underutilized or unnecessary, others faced higher operational demand, indicating a need for load balancing and process optimization (Heizer, Render, & Munson, 2016; Stevenson, 2018).

Table 9.

Entity activity

Name	Total Exits	Current Qty in System	Avg Time in System (MIN)	Avg Time in Move Logic (MIN)	Avg Time Waiting (MIN)	Avg Time in Operation (MIN)	Avg Time Blocked (Min)
Raw Material	550.00	166.00	220.31	167.76	1.03	9.50	42.02

Source: ProModel simulation output

Table 9 presented the entity activity data for raw materials during the simulation. A total of 550 raw materials exited the system, while 166 remained in the system by the end of the simulation. The average time each entity spent in the system was 220.31 minutes, with most of this time (167.76 minutes) spent in move logic, indicating considerable transportation or transfer durations within the system. The average waiting time remained minimal at 1.03 minutes, and the average time spent in operation was 9.50 minutes, suggesting that actual processing time was relatively short. However, the average blocked time was notably high at

42.02 minutes, implying that raw materials frequently experienced delays due to downstream capacity issues or lack of available space. These results indicated inefficiencies in the system's flow and potential bottlenecks that could be mitigated through process redesign or resource balancing (Heizer, Render, & Munson, 2016; Stevenson, 2018).

Discussion

This section presents a comprehensive analysis of the key findings of the study in relation to the research objectives and existing literature. The results highlight several critical inefficiencies and systemic issues within the production process of Peppermint Tailoring, a low-volume manufacturing firm. The insights derived from time-and-motion studies, simulation modeling, and worker feedback are discussed below.

1. Low Production Efficiency

The baseline production efficiency of Peppermint Tailoring was recorded at 73.08%, derived from a comparison between the actual output rate (59.375 T-shirts per hour) and the standard output rate (81.25 T-shirts per hour). This considerable discrepancy underscores the presence of systemic inefficiencies in the current manufacturing setup. According to Heizer, Render, and Munson (2016), a production efficiency below 80% in a controlled manufacturing environment is indicative of operational shortcomings such as inadequate workflow design, underutilization of labor or machines, or excessive idle time. The low efficiency figure in this study validates the need for an immediate redesign of production processes and layout optimization.

2. Inefficient Facility Layout and Idle Stations

Simulation results revealed that the Box Station and Curing Station had 0% utilization across both the baseline and proposed layouts. These stations remained idle for the entire 8-hour production simulation, suggesting their redundancy or improper integration into the production workflow. This observation aligns with the findings of Russell and Taylor (2017), who emphasized that inefficient facility layouts often lead to unnecessary workstation inclusion, thereby increasing the complexity of movement and reducing overall throughput. The presence of idle stations also contributes to wasted space and extended transportation paths, both of which are critical issues in lean manufacturing systems.

3. Imbalanced Resource Utilization

The study found significant disparities in the utilization of production stations. The Printer Station exhibited the highest activity, with a utilization rate of 41.94%, processing 593 entries. In contrast, the Packing and Finish End Stations showed significantly lower utilization rates of 2.74% and 1.90%, respectively. These figures indicate a mismatch in task allocation and workflow balancing, resulting in uneven workload distribution. According to Heizer et al. (2016), such imbalances can lead to bottlenecks at highly utilized stations and underperformance at others, reducing the system's overall effectiveness. Therefore, realignment of task responsibilities and production scheduling is essential to achieve a more synchronized workflow.

4. Excessive Material Handling and Production Blockages

The analysis of simulation data showed that raw materials spent 82.10% of their time in movement logic, with an additional 12.33% being blocked due to downstream constraints, while only 5.02% of time was devoted to actual operations. On average, materials were blocked for 21.23 minutes and moved for 173.49 minutes, out of an average total system time of 205.51 minutes. These figures demonstrate an overwhelming presence of non-value-adding activities in the form of excessive movement and waiting. As Stevenson (2018) notes, excessive transport and handling are classic forms of waste in lean systems, contributing directly to lower efficiency and higher production lead times. Optimizing material flow through improved layout and station placement is therefore critical.

5. Suboptimal Working Conditions

Field observations and employee interviews identified several environmental and ergonomic concerns within the production area. Poor ventilation, cramped workspaces, and inadequate lighting were repeatedly mentioned as factors contributing to worker fatigue, physical discomfort, and decreased productivity. Narayanamurthy and Gurumurthy (2016) highlight that ergonomically deficient work environments not only increase the risk of occupational injury but also lead to decreased motivation and morale among workers. These conditions, if unaddressed, can lead to long-term health issues and high employee turnover, both of which are detrimental to organizational performance.

6. Lack of Responsive Management Structures

The study also revealed the absence of a formalized mechanism for capturing and acting upon worker feedback. Despite clear indicators of tool misplacement, ergonomic inefficiencies, and environmental discomfort, no procedures were in place to incorporate employee insights into operational decision-making. This gap reflects a lack of participative management and continuous improvement of culture, which are essential components of lean and agile production systems. As observed by Stevenson (2018), failure to integrate bottom-up feedback can result in persistent operational inefficiencies and missed opportunities for innovation.

7. Neglect of Worker Well-Being

Closely linked to the working conditions is the broader issue of employee well-being, both physical and psychological. Workers reported feeling overheated, crowded, and mentally fatigued, particularly in areas lacking adequate airflow or personal space. This aligns with the findings of Afonso, Monteiro, and Paisana (2018), who emphasized that ergonomic and environmental stressors contribute significantly to low job satisfaction and suboptimal performance. Promoting a safe, comfortable, and supportive work environment is therefore not merely a compliance issue but a strategic imperative for enhancing productivity and employee retention.

8. Absence of Occupational Safety Measures

Despite the presence of high-temperature machinery and pressurized equipment, the study found that workers were not provided with basic personal protective equipment (PPE) such as gloves and heat-resistant clothing. This exposes employees to serious health and safety risks, potentially resulting in injury, absenteeism, and legal liabilities for the company. Zhan et al. (2021) emphasized that safety measures are non-negotiable elements of industrial operations, especially in environments involving thermal or mechanical hazards. The current lack of safety protocols reflects a critical oversight in management practices and requires immediate remediation.

Conclusion

This study took a deep look at the production challenges faced by Peppermint Tailoring, a small-scale T-shirt manufacturer operating in a low-volume environment. The results confirmed what was initially suspected: the current system had serious inefficiencies, with a baseline production efficiency of just 73.08%. Through a combination of industrial engineering tools and simulation modeling, the research team was able to design two alternative facility layouts—raising efficiency to 84.62% and 89.23%, respectively. These improvements show that even small changes, when backed by data, can lead to big gains in productivity.

One of the major issues uncovered was the presence of idle or underutilized workstations, particularly the Box and Curing Stations. These areas weren't contributing to the production process but were still taking up space and adding complexity. Redesigning the layout helped eliminate these inefficiencies and created a smoother, more direct workflow. It also helped redistribute tasks more evenly, especially between busy stations like the Printer and less active ones like Packing and Finish End.

Another significant finding was the amount of time raw materials spent in unnecessary movement—over 80% of the time in some cases. Reducing this kind of non-value-adding activity through better layout and more efficient handling dramatically improved overall flow and reduced delays. But the problems weren't just technical. The study also revealed human-centered issues like poor ventilation, cramped workspaces, and a general lack of attention to employee comfort and safety. These conditions were affecting both morale and performance. Simple interventions—such as improving airflow, organizing work areas, and scheduling regular breaks—could make a big difference in how employees feel and work throughout the day.

Management's lack of responsiveness to employee concerns was another barrier. Without proper channels for feedback, recurring issues were going unaddressed. Introducing formal feedback mechanisms and involving workers in improvement discussions could help create a more adaptive and efficient workplace culture.

Perhaps most concerning was the absence of proper safety measures. Workers were handling hot and potentially dangerous equipment without basic protective gear like gloves or heat-resistant clothing. This isn't just a productivity issue—it's a serious risk to health and safety. The company must prioritize regular safety checks and provide appropriate protective equipment to ensure worker wellbeing.

In summary, the study demonstrated that process efficiency in small, low-volume manufacturing settings can be significantly improved through practical, data-informed strategies. Addressing both the technical and human aspects of production led to real improvements—and these findings can serve as a model for similar businesses.

For future researchers, there's room to build on this work. Expanding the analysis to include cost savings, energy use, or long-term performance would provide a fuller picture of the impact of these changes. It would also be useful to explore how digital tools like real-time tracking systems or smart sensors could support continuous improvement. Comparing results across different companies or industries could help refine best practices that others can apply in their own unique contexts. Most importantly, future studies should continue to focus not just on the process, but on the people—because sustainable improvement depends on both.

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