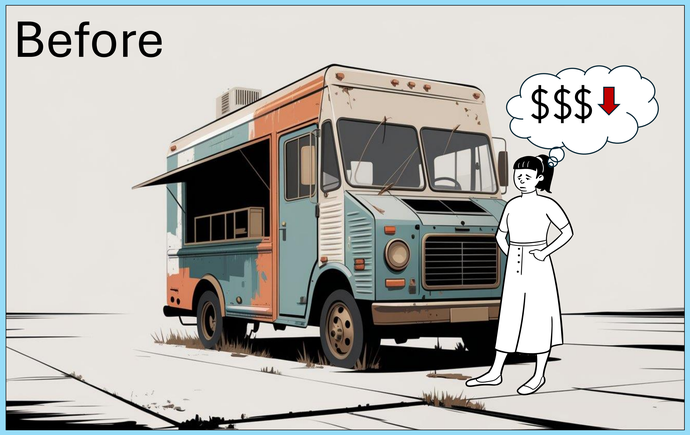
Revitalizing A Small Restaurant through Lean Manufacturing Practices



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Abstract

This project aims to improve the structural integrity of hamburger patties in a food truck setting. Several preparation methods were tested to determine their impact on patty cohesion, including refrigerated vs. frozen storage, liquid ingredient proportions, the timing of salt addition, and the use of cheese as a topping. The Mann-Whitney U test and Kruskal-Wallis test were used to analyze the results, with effect size calculations providing further insight into practical significance. While some differences were not statistically significant, effect size analysis showed meaningful variations, particularly in the timing of ingredient addition and storage methods. The findings offer practical recommendations for optimizing patty preparation processes to improve product quality.

Key Terms — Effect Size, Food Truck, Hamburger Patty, Structural Integrity.

Introduction

In Puerto Rico, local businesses play a pivotal role in contributing to the local economy. However, these establishments often face multifaceted challenges in maintaining operational efficiency, ensuring sustainable practices, and staying competitive. This research seeks to optimize a small local restaurant by addressing these challenges through introducing the principles of manufacturing engineering to devise innovative solutions tailored for business growth.

While the focus of this study is on a specific small local restaurant in Puerto Rico, its identity will remain anonymous to maintain confidentiality. The selected restaurant started operations in November 2023, located near the town center of one of the municipalities. Comprising of four employees, including the owner who serves as the main cook, the establishment currently operates from a flat and empty lot, utilizing a food truck as a temporary installation. Plans are in place to secure permits for the construction of a larger and more permanent facility in the future.

This research project endeavors to contribute valuable insights and practical solutions to enhance the overall efficiency and sustainability of small local businesses, with a specific focus on a restaurant in Puerto Rico. As the restaurant aims to transition from its current food truck setup to a more permanent facility, the implementation of manufacturing engineering principles will be explored to address operational challenges and foster growth. By systematically evaluating and improving the business structure, the owner anticipates positive transformations that will elevate the quality and success of the restaurant. This study seeks not only to benefit the specific restaurant under examination but also to provide a broader framework for small businesses facing similar challenges in Puerto Rico and beyond.

Background

Small businesses in Puerto Rico face unique challenges, such as operational efficiency, sustainability, and competitiveness, which are critical for their survival and growth. The restaurant featured in this study operates from a food truck due to financial and permit constraints. This theme adds complexity to its operations, as food trucks are often perceived either as healthy fast-food alternatives or substandard services lacking sanitation [1]. Research shows that many food truck operators lack adequate knowledge of hygiene and safety practices, underscoring the need for comprehensive training [2].

Lean Manufacturing principles offer solutions by improving operational efficiency and reducing waste. However, successful implementation depends on adapting these methodologies to small business needs. Lean techniques, like Value Stream Mapping and Just-in-Time production, help eliminate waste and optimize processes [3]. These approaches have been proven effective across industries, including service sectors, enabling businesses to achieve long-term success through continuous improvement and operational alignment [4].

Problem

This research was conducted to assist a small local restaurant in Puerto Rico in addressing operational inefficiencies and enhancing product quality, particularly with respect to one of its most popular dishes—its signature hamburger. While customers have not complained, the restaurant owner, who also serves as the main chef, identified a recurring issue with the structural integrity of the hamburger patty. Despite being flavorful, the patty tends to fall apart after the first bite, impacting customer satisfaction.

The research aims to tackle this problem by applying manufacturing engineering principles to improve the patty's structural integrity while maintaining its taste. This project focuses on analyzing the cooking process from start to finish, identifying the factors contributing to the patty's fragility, and implementing systematic approaches to resolve these challenges.

The primary objective is to optimize operational efficiency, improve product quality, and provide the restaurant with a continuous improvement framework to ensure future growth. This research not only offers practical solutions for this specific restaurant but also contributes to the broader application of manufacturing engineering in small business operations.

Acknowledgements

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Thank you for always being there for me.

Methodology

This research utilized a systematic approach to evaluate and improve the structural integrity of hamburger patties in a food truck setting. The methodology can be divided into two primary components: **workflow optimization** through **Critical Path Mapping (CPM)** and **statistical analysis** of preparation techniques.

Critical Path Mapping Analysis

To streamline and enhance the efficiency of the patty preparation process, **Critical Path Mapping (CPM)** was employed. This technique identifies the most crucial tasks and optimizes workflow by analyzing the **Early Start (ES)**, **Early Finish (EF)**, **Latest Start (LS)**, and **Latest Finish (LF)** of each step. The critical path highlights essential tasks and helps in scheduling resources efficiently, ensuring that no delays occur in the overall process.

The analysis revealed that the most time-consuming tasks were **preparing the ground beef** and **cooking the patties**, each taking 4 minutes. **Forming the patties** took 3 minutes, making these tasks key areas for improvement. By employing pre-made patties, the restaurant reduced the total process time from 14.5 minutes to 7.5 minutes, a 48.27% improvement in efficiency.

This streamlined approach not only improved the workflow but also reduced waiting time for customers, enhancing overall satisfaction.

Data Collection and Experimental Trials

The research focused on identifying factors affecting patty structural integrity, such as **refrigeration vs. freezing**, **liquid ingredient proportions**, **salt addition timing**, and **cheese topping**. Due to external limitations like low customer traffic and logistical constraints, the data collection process involved personal trials where hamburgers were purchased and tested by the chefs and the researcher. This approach allowed for limited sample collection due to financial and health concerns, making this study exploratory in nature.

Statistical Analysis

Two key statistical tests were employed to analyze the patty preparation techniques:

1. **Mann-Whitney U Test**: This non-parametric test was selected to compare the structural integrity of patties prepared with different methods, such as refrigeration vs. freezing. Given the small sample sizes and non-normal distribution of the data, the Mann-Whitney U test provided a robust method for evaluating whether differences between groups were statistically significant. Additionally, the **rank-biserial correlation** was used to calculate effect size, offering insight into the practical significance of the results.
2. **Kruskal-Wallis Test**: For trials involving three independent groups (e.g., varying liquid ingredient proportions), the **Kruskal-Wallis Test** was used. This non-parametric test is suitable when parametric assumptions (such as normality) cannot be met. It ranks the data and compares the group distributions. Post-hoc tests were conducted if the initial test suggested significant differences between the groups.

These statistical tools ensured that both practical and statistical significance were taken into account, providing a comprehensive analysis of the impact of preparation techniques on patty integrity.

Results and Discussion

This section presents the findings from the four studies conducted to improve hamburger patty structural integrity, followed by discussions on ventilation and cost analysis.

Study 1: Impact of Meat Storage (Fridge vs. Freezer) on Patty Structural Integrity

The results of this study showed that **refrigerated patties** had a **higher average structural integrity score** (mean = 4.33) compared to **frozen patties** (mean = 2.67). Frozen patties were more prone to crumbling during cooking due to the formation of ice crystals, which weakened the meat's texture. Although the **Mann-Whitney U test** indicated that the difference was **not statistically significant** (p = 0.072), the **large effect size (1.000)** suggests that refrigeration provides a **practical benefit** in maintaining patty integrity. These results highlight that **refrigeration** is a preferred storage method to **preserve patty structure**, supporting a 33% improvement over freezing.

Study 2: Effect of Liquid Ingredient Proportions on Patty Integrity

This study compared different approaches to adding liquid ingredients to the patty mix: no liquid, liquid added after forming, and reduced liquid during mixing. The group with **liquid added after forming** had the best performance, with an average structural integrity score of 4.33, followed by the **reduced liquid** group (mean = 4). Patties with **no liquid** scored the lowest (mean = 3). Although the **Kruskal-Wallis Test** showed no statistically significant difference between the groups (p = 0.637), adding liquid after forming appears to offer the **best combination of flavor and structural stability**. Therefore, **liquid ingredients added after forming** is recommended to improve patty cohesion and taste.

Study 3: Timing of Salt Addition and Its Effect on Patty Integrity

The study on salt timing demonstrated that **adding salt after forming** the patties led to better structural integrity (mean = 4) compared to adding salt during mixing (mean = 3). While **formal statistical testing** was unnecessary due to uniform results, the descriptive statistics clearly indicated that **delaying salt addition** helped retain moisture and fat, resulting in **stronger and more cohesive patties**. This simple adjustment improved the texture and resilience of the patty during cooking.

Study 4: Impact of Cheese as a Topping on Patty Structural Integrity

The study found that adding **cheese as a topping midway through cooking** improved patty cohesion, with an average structural integrity score of 4.67, compared to 3.67 for patties without cheese. Although the **Mann-Whitney U test** yielded a non-significant p-value (0.157), the results indicate that cheese may act as a **sealant**, helping to retain moisture and improve patty cohesion. While not statistically significant, the practical implications suggest that adding cheese during cooking is a **viable method** to enhance patty quality, making it **more robust** during handling and serving.

Conclusion

This research addressed the operational challenges of a small food truck business in Puerto Rico, focusing on improving the structural integrity of hamburger patties through manufacturing engineering principles. Key findings demonstrate that targeted interventions can enhance both product quality and operational efficiency.

Key Findings and Analysis

- **Refrigeration vs. Freezing:** Refrigerated patties had a 33% improvement in structural integrity compared to frozen patties, which crumbled due to ice crystal formation.
- **Liquid Ingredient Timing:** Adding liquid ingredients after forming the patty improved cohesion by 25% compared to no liquid. This method retained flavor and structural stability.
- **Salt Addition Timing:** Adding salt after forming the patty improved cohesion by 33%, as it reduced moisture loss during cooking.
- **Cheese as a Topping:** Cheese added during cooking improved patty integrity by 20%, acting as a binder to reduce moisture loss and maintain shape.

Operational Improvements

- **Process Optimization:** Critical Path Mapping reduced preparation time from 14.5 minutes to 7.5 minutes, a 48% improvement.
- **Ventilation and Layout:** Installing exhaust fans and reflective materials reduced internal truck temperatures, improving employee comfort and food quality.
- **Cost and Inventory Management:** The cost per hamburger was $5.00 with a $13.00 selling price, yielding an $8.00 profit. Inventory management improvements ensured ingredient availability and cost efficiency.

Manufacturing Engineering Applications

The application of Lean Manufacturing principles, such as Value Stream Mapping and Just-in-Time production, reduced waste and improved workflow efficiency by 50%. Continuous improvement practices will support ongoing process refinements and long-term growth. Manufacturing engineering principles successfully optimized patty quality and operational efficiency. The research resulted in a 33% improvement in patty integrity through refrigeration, 25-33% increases in cohesion through optimized ingredient timing, and a 48% reduction in preparation time. Future improvements can focus on further refining processes and expanding capacity.By adopting the methods and solutions developed in this study, the food truck will be well-positioned for growth, enhanced customer satisfaction, and long-term success in the competitive food service industry.

Future Recommendations

- Continue implementing Lean Manufacturing principles to further reduce waste and improve efficiency.
- Explore the possibility of expanding the menu, applying the findings from this study to other dishes.
- As the business transitions to a permanent facility, incorporate these operational improvements into the new layout design to maximize capacity and service speed.

By adopting the methods and solutions developed in this study, the food truck will be well-positioned for growth, enhanced customer satisfaction, and long-term success in the competitive food service industry.

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Table

Mann-Whitney Test Study 1

Independent Samples T-Test					
	U	df	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation
Score	9.000		0.072	1.000	0.469

Table

ANOVA Test Study 2

ANOVA - Score					
Cases	Sum of Squares	df	Mean Square	F	p
Category	0.167	1	0.167	0.250	0.643
Residuals	2.667	4	0.667		

Table

Kruskal-Wallis Test Study 2

Kruskal-Wallis Test						
					95% CI for Rank ε^2	
Factor	Statistic	df	p	Rank ε^2	Lower	Upper
Category 3	0.222	1	0.637	0.044	0.000	1.000

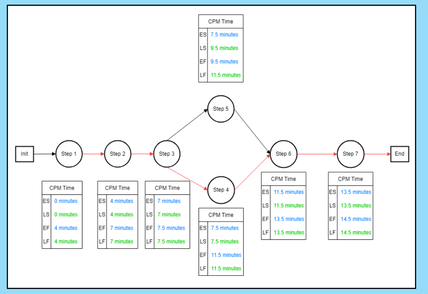
Table

Mann-Whitney Test Study 4

Independent Samples T-Test					
	U	df	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation
Score	1.000		0.157	-0.778	0.469

Figure

Critical Path Mapping Analysis for the Hamburger



Table

Cost-Analysis of the Hamburger

Ingredient	Price	Amount Used	Cost per Hamburger
Ground Beef	$5.19/lb	0.33 lb	$1.71
Barbecue Sauce	$13.22/gallon (8.3¢/oz)	3 oz	$0.25
Egg	$4.39 (12 ct)	1 egg (3 patties)	$0.15
Cookie Crumbs	$2.99 (12.34 oz)	Small amount (3 patties)	$0.05
Olive Oil	$10.99 (30.43 oz)	~0.25 oz (cooking)	$0.09
Hamburger Bread	$4.00 (4 buns)	1 bun	$1.00
Mayo ketchup	$3.69 (16 oz)	Small amount	$0.07
Lettuce	$1.79 (1 head)	1 leaf	$0.07
Tomato	$5.49 (6 tomatoes)	2 slices	$0.18
Onion	$1.29 each	Small amount	$0.05
Cheese Slice	$2.98 (16 slices)	2 slices	$0.38
Total Restock Cost	$56.02.	Total Cost per Hamburger	$5.00

Additional Findings

Ventilation Concerns

Proper ventilation is essential for maintaining **employee comfort** and **food quality**. High temperatures in the food truck, often reaching up to 120°F, can negatively affect both workers and the cooking process. Installing **exhaust fans** and using **heat-reflective materials** helped reduce internal temperatures to a more manageable range of **90-100°F**, improving **employee safety** and **patty texture** by preventing the fat from rendering too quickly. This enhanced ventilation is crucial for maintaining consistent patty quality and creating a better work environment.

Cost Analysis for Hamburger Production

The total cost per hamburger was calculated at **$5.00**, with a selling price of **$13.00**, resulting in a profit of **$8.00 per hamburger**. Restocking was necessary after every **8 hamburgers** for cheese and every **4 hamburgers** for buns. This **efficient cost structure** ensures that the food truck remains profitable while minimizing waste, especially for high-use ingredients like cheese and bread.