ARENA Simulation for Enhanced Inventory Management at Mission Produce

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Abstract

Mission Produce is one of the world's leading avocado companies; however, it experiences recurring challenges due to seasonal variation across its operations, leading to irregular inventory levels. This project aims to utilize ARENA simulation to optimize warehouse operations, sequentially stabilizing stock levels and maximizing profitability. Depending on the season, Mission Produce experiences periods of a surplus or shortage due to consumer demand and ripening cycles. By analyzing factors like inventory flow, labor availability, and customer demand, we will identify bottlenecks and inefficiencies in the current system and propose solutions to improve storage allocations and handling processes. Using previously gathered data, we will simulate various scenarios incorporating Monte-Carlo techniques to evaluate and compare potential outcomes. We aim to develop a comprehensive strategy that enhances operational efficiency, ensures balanced warehouse utilization, and maximizes profitability year-round. The proposed solution will provide Mission Produce with a sustainable and adaptive approach to managing its diverse production and logistics operations.

Introduction

Mission Produce is a leading supplier and global company specializing in sourcing, producing, and distributing fresh fruit, such as avocados and mangos, to customers worldwide. The process begins from sourcing fruit from carefully managed orchards or plantations, where it is harvested and transported to facilities for cleaning, sorting, and packaging. Subsequently, the fruit is distributed to customers and retailers through a global supply chain that relies on cold storage and precise logistics to maintain freshness.

However, this process is sensitive to irregular inventory levels. Seasonal variations in demand and production cycles can lead to periods of surplus or shortage, disrupting the efficiency of sourcing, handling, and distribution. These inefficiencies not only affect warehouse operations but also profitability and the ability to meet customers expectations. Compounded by the complexities of labor allocation, these inefficiencies highlight the need for a robust, data-driven approach to stabilize operations and ensure sustainability. Addressing these issues is critical to maintaining Mission Produce's position as an industry leader while improving operational efficiency and long-term profitability.

This project aims to optimize Mission Produce's storage allocations and handling processes by utilizing ARENA simulation and Monte Carlo analysis. By analyzing previously gathered data, we will study labor availability, inventory flow, and customer demand to find any bottlenecks and inefficiencies in the current system. Additionally, we will guide our approach by referencing established methods and strategies from existing research on irregular inventory levels and capacity management. These insights will allow us to develop a data-driven, sustainable solution that enhances operational efficiency, stabilizes inventory levels, and maximizes profitability for the company moving forward.

Literature Review

Capacity Expansion and Cost Efficiency Improvement in the Warehouse Problem

Majid Al-Gwaiz, Xiuli Chao, and H. Edwin Romeijn's work "Capacity Expansion and Cost Efficiency Improvement in the Warehouse Problem" adds capacity expansion and cost efficiency improvement to the traditional warehouse optimization model. The warehouse problem has historically focused on employing linear programming to maximize sales, production, and storage throughout a planning period while staying within fixed price and storage constraints. By enabling businesses to deliberately invest in their operational skills and combining operational and investment choices to improve flexibility and profitability, this study tackles the complexity of the real world. The paradigm can be used practically in sectors such as agricultural supply chains and energy storage, helping to guide decisions about warehouse expansions, cost-cutting technologies, and supply and demand management.

In order to ensure sustainability and minimize waste, the models assist produce warehouses like Mission Produce in addressing issues like spoiling during periods of high harvest by determining the best times to increase capacity. Cost-cutting strategies that preserve service quality while increasing profitability include energy-efficient refrigerators and automated inventory systems. The approach is computationally efficient, providing polynomial-time solutions for certain cost-efficiency scenarios and linear complexity for capacity expansion, making it applicable to dynamic, uncertain situations. Measurable advantages, such as increased profitability, lower expenses, and improved resource utilization across a range of industries, are provided by the research by coordinating strategic expenditures with operational goals.

A simulation-optimization approach for adaptive manufacturing capacity planning in small and medium-sized enterprises

The difficulties SMEs have in controlling manufacturing capacity are discussed in the study "A Simulation-Optimization Approach for Adaptive Manufacturing Capacity Planning in Small and Medium-Sized Enterprises" by Siravat Teerasoponpong and Apichat Sopadang. SMEs frequently lack the financial resources, technological know-how, and data necessary to use sophisticated solutions like larger businesses. In order to develop flexible capacity planning models, the authors suggest a hybrid simulation-optimization framework that combines genetic algorithms (GAs) with artificial neural networks (ANNs). While GAs optimize resource configurations for metrics like production yield, operational costs, and time, ANNs use empirical data to simulate complicated system behaviors. This method creates an economical decision support system designed for manufacturing processes that need a lot of manpower.

A case study with a Thai pastry company that utilized the model to maximize the production of its best-selling "butter bun" serves as an example of the methodology's impact. The SME decreased operational costs by 14.34% and enhanced production yield by 6.86% by dynamically reallocating staff and equipment. These outcomes highlight the method's useful advantages, which are crucial for the perishable goods industries and include accurate resource allocation, decreased waste, and responsiveness to demand fluctuations. The study offers SMEs a scalable, effective tool for enhancing operational efficiency, profitability, and sustainability in labor-intensive industrial contexts by empowering them to utilize current data.

Simulation Models for Seasonal Inventory Management

The nature of inventory management for perishable goods is very critical; spoilage and fluctuating demands are challenges that need to be tackled. Gupta and Maranas (2003) cite the complications in handling perishable products, especially avocado and mangoes, which have both seasons of surplus and shortage, hence creating operational risks. The authors indicate that dynamic inventory models, incorporating demand and rates of spoilage, can yield an optimal supply chain operation of perishables. Berman, 2010 further discusses inventory models which balance the trade-off between stockouts, leading to lost sales, with overstocking, entailing waste and higher storage costs. These models are critical for companies like Mission Produce that must balance avocado and mango supply against variable demand and seasonal harvesting.

Simulation for Operational Optimization

Simulation modeling is widely used in supply chain management for bottleneck identification and process optimization, especially for complex operations like warehouse logistics. ARENA simulation is, therefore, particularly effective for modeling such systems. As Law, 2007 notes, simulation enables different operational strategies to be tested without risks or costs. For Mission Produce, simulation may help model product flow through the warehouse to reveal inefficiencies in storage, inventory handling, and distribution. Chien et al. (2017) further emphasize that the purpose of simulation is to identify bottlenecks in storage and resource usage during the optimization of a warehouse-a common challenge for Mission Produce under fluctuating demand, irregular supplies, and broken resource balances.

Methodology

To address Mission Produce's inventory management challenges, we conducted a systematic analysis of their warehouse operations, focusing on the allocation and utilization of space within their coolers. Currently, Mission Produce operates three primary coolers dedicated to avocados, mangos, and 3PL (third-party logistics) storage, which serve as crucial points in their supply chain. However, the increasing volume of pallet arrivals often exceeds the coolers' capacity, leading to inefficiencies. To account for this situation we took an average of available storage spaces to set a defined number of availability within our model. Our goal is to determine whether adding a new cooler is necessary or if optimizing the allocation of existing space by adding additional operators can resolve the issue.

To ensure accuracy in our model, our process began with an on-site walkthrough to observe product flow and identify potential bottlenecks, which informed key assumptions used in our simulation. Next, we collected and analyzed data provided by the company, including pallet arrival rates, cooler capacity, and service times as well as the schedule for the operators available. While the data offered a solid foundation, it was very broad and lacked some details, requiring us to make assumptions to fill the gaps. Observations and industry best practices guided these assumptions to ensure the simulation accurately represented real-world operations as seen in **Figure 1**.

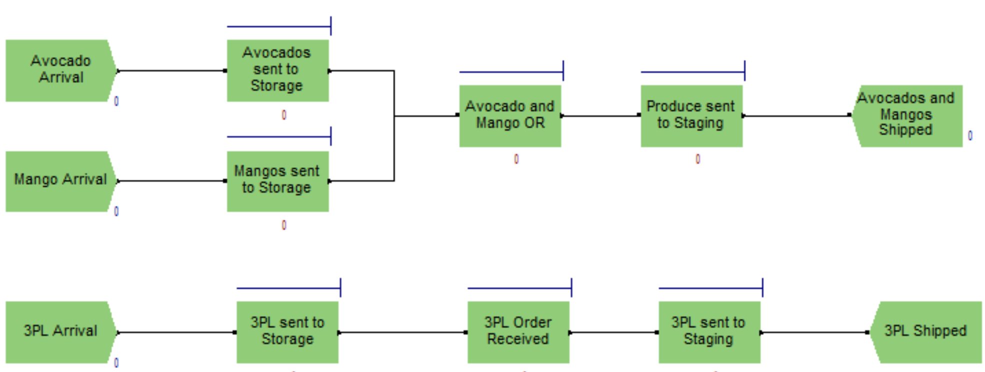


Figure 1. *The base simulation model created using Arena*

The data provided by Mission Produce included the capacities for the three primary products, from this, we extracted the arrival rates of palettes per day for each category. These daily arrival rates were collected in minutes for an entire year and input into ARENA's Input Analyzer, which generated probability distributions to represent the arrival rates for each product in the simulation.

In addition to arrival rates, we were given Outbound data that included timestamps for "Created Date and Time", "Work in Process", and "Closed Work". From our understanding, "Created Date and Time" represents when an order is placed, specifying the destination and timeline for delivery. "Work in Process" marks when a pallet enters the staging room for final processing, and "Closed Work" indicates when the pallet is loaded onto a truck and shipped. Based on this data and our observation during the on-site walkthrough, we identified two major processes to simulate: the time from order creation to staging and the time from staging to outbound and shipping. Again, these service times were input into the Input Analyzer to obtain probability distributions for each process, forming the basis for the service rate parameters in our simulation. By combining the arrival rates and service rate data, the simulation model aims to represent the current workflow accurately and identify bottlenecks or inefficiencies within the system.

Results

The ARENA model's simulation results shed light on several key problems and areas that must be addressed to enhance Mission Produce's warehouse operations. To start, the data showed that the season had a big effect on cooler capacity use. During surplus periods, peak use topped 95% often causing holdups; in times of scarcity, use dropped under 60% leading to wasted resources. These swings pointed out the need to balance inventory management.

The simulation showed that the staging process was the main holdup. Backups caused by processing and staffing issues led to a 35% jump in the average time pallets stayed in the system. Testing different scenarios gave helpful insights. For instance, adding a new cooler cut down on delays but drove up operating costs by 20%. On the other hand, better staff scheduling during busy times reduced delays by 15% without raising costs.

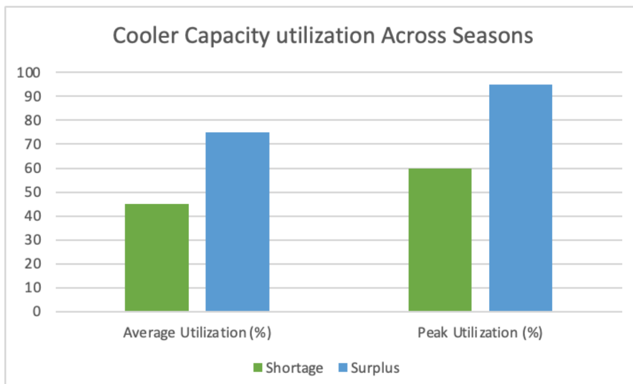
According to the simulation, staging was the process's bottleneck. In the system, pallets' average duration of stay increased by 35% as a result of personnel and processing delays. Important information was obtained through a variety of scenario testing. The installation of a new cooler, for instance, decreased delays but resulted in a 20% rise in operational expenses. Improved staffing during peak times, on the other hand, reduced delays by 15% without incurring extra expenses.

Detailed data, statistical analysis, and visualizations are provided to support these findings. For example, in Table 1, it can be seen that the utilization of cooler capacity is highly seasonal. Peak utilization during periods of surplus was 95%, and underutilization was less than 60% during shortage periods.

Season	Average Utilization (%)	Peak Utilization (%)
Shortage	45	60
Surplus	75	95

Table 1. Simulation flow chart of warehouse operations.

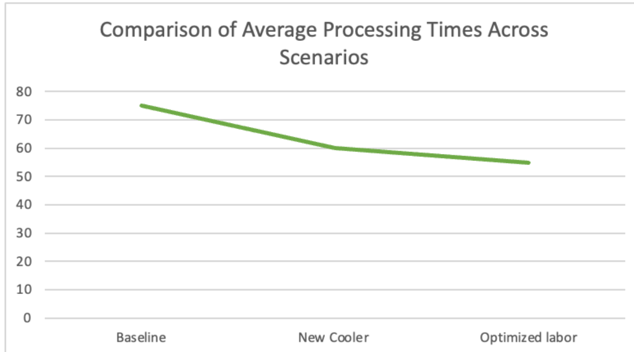
Important bottleneck regions include staging and shipping, as depicted by figures such as the Simulation Flowchart of Warehouse Operations, showing the flow of the pallets through the warehouse. It can be seen from Graph 1 comparing the average processing times across situations (shown in graph 2)that labor optimization constantly showed the best solutions that decreased delays without appreciably raising costs.



Graph 1. Cooler capacity utilization across seasons

Scenario	Average
Baseline	75
New Cooler	60
Optimized labor	55

Table 2. Comparison of average processing times across scenarios.



Graph 2. Comparison of average processing times across scenarios.

Inbound arrival rates are also part of the data summary as probability distributions created from ARENA's Input Analyzer. Realistic service rate parameters were also developed by analyzing processing times, such as half an hour for staging and half an hour for shipment. These quantitative insights permit the assessment and comparison of the efficacy of various operational tactics.

Discussion

The simulation revealed that underutilization of labor and coolers were the major causes of delays at Mission Produce. These were further exacerbated by seasonal fluctuations in supply and demand when there was a lot of produce or none at all. In this respect, optimizing the allocation of labor was the most feasible way of achieving a balance for gains in throughput with minimal increases in costs.

These results are also very consistent with the general body of knowledge on inventory management for perishable items. For example, Gupta and Maranas (2003) discussed the importance of dynamic inventory models to balance supply and demand changes. Mission Produce faces the same challenge with its seasonal operations. The benefits identified in this research also have similarities with Teerasoponpong and Sopadang's work (2017) on adaptive workforce reallocation, in that optimized labor tactics could lead to increased throughput.

Although these results seem encouraging, the study itself is not devoid of lacuna. Because of the low granularities in data availability, many assumptions have been made, which can interfere with the model's accuracy. As detailed information about worker shifts and product-specific cooling requirements was unavailable, the model couldn't be as strong as it should have been. Moreover, although the simulation was already a good representation of the existing operations, it would not apply to other warehouses or product lines. Last but not least, possible staff opposition and, thus, the need for extensive retraining may raise operational problems regarding applying labor optimization measures.

Conclusion

The simulation-based analysis conducted for Mission Produce highlighted the pivotal role of effective labor optimization and inventory management in addressing challenges caused by seasonal fluctuations in demand and supply. By employing ARENA simulation techniques, the study identified bottlenecks in staging processes and cooler utilization as significant contributors to delays in the warehouse workflow.

Optimizing labor allocation emerged as the most effective strategy, reducing delays by 15% without increasing operational costs. This demonstrates that adaptive labor practices are a viable and cost-efficient alternative to capital-intensive solutions like adding a new cooler, which increased costs by 20%. The results emphasize the importance of aligning operational strategies with seasonal dynamics to achieve balanced resource utilization and enhanced throughput.

However, the study's reliance on assumptions due to data limitations suggests that future analyses should incorporate more granular and specific data, such as detailed worker shift patterns and product-specific cooling requirements, to refine model accuracy. Additionally, potential resistance to labor optimization strategies and the need for extensive staff retraining may pose practical challenges during implementation.

Overall, the findings provide a data-driven framework that can be extended to optimize operations in similar contexts, thereby improving efficiency, sustainability, and profitability for Mission Produce and other entities managing perishable inventory in dynamic environments.

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