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Faculty of Engineering
Department of Industrial Engineering

An Adaptive Production Planning Model for Heavy Equipment Manufacturing Industry

Project Report

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Minimizing the Cost of Food Waste in a Hotel Restaurant

A Project Presented
by

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Abstract

In the hospitality sector, food waste has become a major problem that contributes to both environmental damage and economic inefficiencies. Because of the perishability of ingredients, overproduction, and varying client demand, hotel restaurants are especially vulnerable to waste. By using a mathematical optimization model based on operations research, our project aims to reduce food waste in Azure Bosphorus, one of the most prestigious restaurants of Taksim, a four-star hotel restaurant in Istanbul.

Ingredient waste, unmet food waste, and plate waste are the three main categories into which the prepared model by us divides food waste. This model determines the ideal preparation quantities for each dish over several daily meal intervals by combining demand projections, kitchen capacity, and customer satisfaction limitations. The model we have built seeks to strike a balance between cost-effective and sustainable operations and good service quality using actual operational data.

Our project adds to the expanding subject of sustainable operations in the hospitality industry by offering an organized, data-driven methodology. Better inventory and production planning are made possible by the findings, which also provide a framework for decision making that may be applied to other service-based food settings. Our focus on this study demonstrates how mathematical modeling can help food service managers close the gap between sustainability and operational efficiency.

Acknowledgments

Without the constant assistance, direction, and encouragement of many people who have been crucial to our academic journey, this graduation project would not have been able to be completed successfully.

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We would like to express our gratitude to the management and employees of the Azure restaurant for kindly sharing their operational data and insights, which made it possible for our research to be put into practice. The success of the project we made was largely due to their cooperation and candor.

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Contents

List of Figures

List of Tables

Chapter 1 Overview

1.1 Introduction

Effective resource use is essential for success in the contemporary hotel sector, not only for guaranteeing client satisfaction but also for tackling growing environmental and financial issues. Hotel restaurants, especially those in crowded urban locations, have a difficult time striking a balance between providing excellent service and using sustainable business practices. Food waste is one of the most urgent problems in this situation, as it has an impact on the environment and the finance of the hotel and its restaurant.

Part of the Metropolitan Hotels family, the Azure Bosphorus Restaurant is a four-star restaurant that serves a varied clientele daily cooked and buffet-style meals. Due to over-preparation, varying customer demand, and the short shelf life of some foods, the restaurant has been facing significant amounts of food waste despite its dedication to culinary quality and customer happiness. Hotel management is looking for operational changes because of these inefficiencies, which not only lead to needless expenses but also negatively impact sustainability initiatives.

This research project of ours suggests a mathematical optimization methodology based on operations research ideas to reduce expenses associated with food waste while preserving service quality. The model takes into account the structural limitations of meal preparation, demand uncertainty, and ingredient perishability. This model attempts to provide better informed and flexible decision-making in food production planning by using historical demand data and using predictive analytics.

1.2 Motivation

The growing economic impact of food waste in the hospitality industry and the growing importance of environmental sustainability in operational procedures serve as the two main drivers behind this study.

Recent reports indicate that a significant portion of the food made in the hotel industry is wasted before it is consumed. This not only raises running expenses in hotels like Azure Bosphorus but also runs counter to international environmental objectives. The issue is further exacerbated by the fact that many products, including seafood, are perishable, which restricts their potential for preservation or reuse.

From a managerial perspective, seasonality, hotel occupancy rates, and erratic walk-in traffic are some of the reasons why Azure Bosphorus's consumer demand fluctuates so much. This heterogeneity is not adequately considered by conventional heuristic or experience-based preparedness planning. A systematic, data-driven strategy is therefore becoming more and more necessary to maximize preparation quantities and cut waste.

The promise of operations research and predictive modeling to provide workable and long-lasting answers to actual issues in service systems is what spurred this study. We can assist in bridging the gap between environmental responsibility and operational efficiency by tackling food waste using a formal mathematical model.

1.3 Contributions

Our initiative aims to transform the way food preparation and inventory management are handled in the hotel industry. The goal of this project is to create an optimization-based decision-support tool that employs mathematical modeling and demand forecasts to help restaurant managers make more informed decisions about food supply.

This tool's main goal is to lower the financial and environmental expenses related to food waste. The approach assists in optimizing daily production volumes by tackling major waste sources, including excess preparation, unused components, and uneaten plate portions. This enables restaurant owners to serve food more effectively while reducing food waste, so achieving cost-cutting and sustainability goals.

Additionally, it is anticipated that the makeover will improve the overall dining experience for patrons. The technology guarantees that service quality is maintained while waste is reduced by integrating customer satisfaction levels into the model. It illustrates how, in a field that is becoming more and more competitive, hospitality enterprises must strike a balance between operational effectiveness and visitor expectations.

In the end, our project offers hotel restaurants genuine value by fusing optimization methods with actual operational insights. It illustrates how cutting-edge equipment and operational research techniques may be combined to enhance conventional food service procedures, assisting businesses such as Azure Bosphorus Restaurant in setting the standard for environmentally friendly and effective dining operations.

Chapter 2 Problem Description

The board of directors of Azure Bosphorus, a renowned four-star hotel restaurant in the center of Istanbul, has expressed grave worries in recent months about the increasing amount of food waste that is recorded during daily operations. What was once thought to be a manageable operational inefficiency has now grown into a serious problem with immediate financial repercussions as well as risks to long-term viability. The board called an urgent meeting after becoming concerned about internal audits and growing expenses, and it was decided that quick action was needed to investigate and fix the issue.

In response to this instruction, the management team of the restaurant immediately began working with our research team, providing us with access to logistical information, process logs, and operational data. After speaking with the employees and looking at the restaurant's procedures, it was clear that the waste issue was a direct result of the daily challenges of the hotel food service, which include excessive meal production, quickly shifting client demand, and insufficient forecasting systems.

Azure Bosphorus is subject to strict service requirements. It serves breakfast, lunch, and dinner with a wide operating window that runs from early morning until midnight, and it welcomes a diverse clientele of both internal hotel guests and outside tourists. Variety and freshness are the cornerstones of its culinary renown, and this dedication leads to a sophisticated preparation method that incorporates both daily mainstays and rotating delicacies. However, planning and inventory control are particularly prone to error because of this very intricacy, especially when combined with very perishable items like seafood.

Because of the hotel's stringent quality control procedures, prepared food cannot be saved for the next day once it has been cooked. Furthermore, commodities like proteins and fresh produce have short shelf life and must frequently be used the same day. The inherent unpredictability in client numbers, caused by seasonality, walk-in traffic, and outside events, leads to recurring cycles of excessive preparedness or unfulfilled demand, even with the best planned plans. In addition to causing financial losses, this operational imbalance runs counter to international sustainability initiatives, such those highlighted in the Sustainable Development Goals (SDG) of the United Nations. 12: Responsible Consumption and Production).

Therefore, the requirement of filling this essential gap with a method based on science defines the scope of this research. Our objective is to develop a mathematical optimization model that may be used as a useful tool for decision support. The algorithm will suggest the best amounts to prepare for each meal service by combining factors like customer satisfaction criteria, kitchen capacity restrictions, meal-period-specific demand predictions, and item perishability. In the end, our strategy seeks to achieve a long-term equilibrium between cutting waste, managing expenses, and preserving the excellent service quality for which Azure Bosphorus is renowned.

2.1 Process under Investigation

1. **Service Structure**
    a. The restaurant is open **7 days a week**.
    b. There are **three meal periods daily**: Breakfast (08:00–11:00), Lunch and Dinner (11:00–00:00).
    c. Customers include hotel guests and walk-in customers. Demand varying daily.
2. **Menu**
    - The menu consists of a mix of fixed dishes (prepared daily) and variable dishes.

3. **Food Preparation & Storage**
    a. Some ingredients (e.g., seafood) have short shelf lives and must be used within **24 hours**.
    b. Other ingredients can be stored for **up to 3 days or more**.
    c. Leftover prepared food **cannot be reused the next day** due to hotel quality standards.
    d. Some of the prepared food goes without consumption giving us an unmet food waste

4. **Staffing**

    A minimum of **5 chefs and 8 assistants and 12 waiters** are required per shift.

5. **Customer Demand Uncertainty**
    a. Seasonality, hotel occupancy, and outside events all affect the daily fluctuations in the number of visitors.

2.2 Limitations and Restrictions

The model considers several limitations and restrictions that correspond to actual operating circumstances. These consist of:
Constraints on service hours and scheduling, including three meal periods per day and continuous operation throughout the week with special menu items and fluctuating client demand, special events like Ramadan or Euro2024 happening in İstanbul add even more complexity. A strong and accurate capacity management strategy must be put into place in order to successfully reduce waste in operational operations. Sensitivity analysis, a potent diagnostic tool for assessing intricate mathematical models originated from operations research, can be applied methodically to accomplish this goal. We can investigate how changes in input parameters, such as shifts in demand, the availability of resources, or production limitations, affect the model's results by performing sensitivity analysis. By identifying important factors, improving model reliability, and guaranteeing the system's resilience and adaptability under shifting operational conditions, this in turn promotes better informed decision-making. It is crucial to recognize the inherent constraints and restrictions of sensitivity analysis, even though it makes a substantial contribution to the robustness of the model. These could include the need for precise input data, the computational complexity of large-scale systems, and any potential assumptions or oversimplifications in the original model. Furthermore, the usefulness of sensitivity studies in highly uncertain or dynamic contexts may be limited since they might not accurately capture nonlinear interactions or infrequent but significant events. Sensitivity analysis must therefore be used critically to comprehend its methodological limitations and practical restrictions, even though its incorporation into capacity planning maximizes resource usage and advances the overall objective of waste reduction.Variability and unpredictability in daily client demand caused by external factors, including seasonality, special events, occupancy rates, and unpredictable amounts of walk-in visitors Additionally, unanticipated disruptions such as employee absences, ingredient shortages, or supplier delays may hinder the model's best performance, necessitating backup strategies and real-time adjustments.

Chapter 3 Methodology and Literature Review

Research Design and Modeling Framework

In order to tackle the intricate problem of managing food waste in a hotel restaurant, this study takes a quantitative and analytical method based on operations research concepts. The selected approach aims to convert the current, primarily heuristic decision-making system into an organized, data-driven optimization framework. The goal is to create a deterministic mathematical model that allows food waste and associated expenses to be minimized while maintaining the standard of customer service and honoring the real-world constraints of the restaurant setting.

The research follows a structured methodology composed of four key phases:

Phase I: Problem Definition and System Understanding.

The Azure Bosphorus Restaurant's operating flow, service structure, inventory practices, and existing waste points were all examined during the first phase through in-depth field observations and stakeholder interviews. The focus was on identifying the key factors and limitations, such as menu complexity, storage restrictions, perishable foods, and fluctuating client demand, that influence the production of food waste.

A realistic operational environment for modeling was established by reviewing data from many sources, including purchase records, consumer foot traffic reports, and kitchen logs. This phase sets the groundwork for creating a system that replicates the dynamics and operational limitations of a real restaurant.

Phase II: Mathematical Model Formulation.

A mathematical optimization model was created using the information gleaned from the preliminary analysis. A cost-minimization issue with several interconnected constraints is how the model is constructed. The amounts of each dish to be made and served during each meal period are the main variables.

The goal function reduces the overall cost of waste, which is broken down into three different parts:

- Ingredient Waste: resulting from raw materials wasted during preparation.
- Plate Waste: referring to uneaten food left on customer plates.
- Unmet Food Waste: representing food that is prepared but not served.

The constraints embedded in the model include:

- Capacity constraints based on kitchen limits and resource availability,
- Shelf-life restrictions for ingredients with perishability concerns,
- Service-level constraints to ensure a minimum customer satisfaction threshold,
- Non-negativity and feasibility conditions to ensure implementable solutions.

Phase III: Data Collection and Parameter Estimation

Azure Bosphorus's restaurant database provided historical information on consumer demand, menu composition, item shelf life, and resource availability. Management interviews were used to confirm the information. When appropriate, regression-based demand forecasting and moving averages were among the statistical methods used to estimate each model parameter. Unit cost analysis and waste reports from the kitchen's procurement and disposal logs were used to estimate waste cost coefficients.

Phase IV: Solution and Model Evaluation

GAMS, a programming environment compatible with linear and integer programming solvers, will be used to develop the final optimization model. Following the model's execution utilizing the gathered data, sensitivity analysis will be used to assess the solution's impact on the overall cost and preparation strategy due to changes in demand, waste variables, or satisfaction criteria. Additional validation will be carried out by assessing possible waste reduction, cost savings, and compliance with practical feasibility, as well as by contrasting the model's suggestions with past performance.

Justification of Methodological Choice

The systematic and repeated character of restaurant operations, along with the well-defined and quantifiable goals (waste reduction and cost minimization), support the decision to use a mathematical modeling method. Operations research makes it possible for prescriptive analytics, which, in contrast to simulation-based or solely heuristic approaches, not only examine historical data but also direct future choices under limited circumstances. The approach also supports the theory of sustainable operations management by showing how mathematical models can be used to support both cost-effective and ecologically responsible food service industry practices.

3.1 A Linear Programming Model for Integrated Steel Production Planning

Sets and Indices

- *T:* Set of months in a year (January to December)

- *I*: Set of dishes offered by the restaurant.

Parameters

- D (i, t): Expected customer demand for dish i in month t
- I(i): Ingredient waste factor for dish i (proportion wasted during preparation)
- P(i): Plate waste factor for dish i (proportion uneaten by customers)
- Wf(i): Cost per unit of unmet food waste (prepared but unserved food)
- Wi(i): Cost per unit of ingredient waste
- Wp(i): Cost per unit of plate waste
- K(t): Total kitchen preparation capacity in month t
- r: Maximum allowable waste rate
- α: Minimum proportion of prepared food that is expected to be unmet
- β: Minimum required demand coverage ratio

Decision Variables

- Q (i, t): Quantity of dish i prepared in month t
- S (i, t): Quantity of dish i served to customers in month t

The amount of each dish that should be produced and the amount that is served to clients during each meal period are represented by the decision variables in this model. These factors are essential for figuring out the ideal amounts of food production that meet consumer demand while reducing waste. The approach facilitates effective and economical food planning by modifying these amounts in accordance with anticipated demand and capacity limitations.

Objective Function

- Minimize the total **cost of all waste** (unmet food waste, ingredient waste, and plate waste):

$$\boxed{\min \sum_{i \in I} \sum_{t \in T} [W_i \cdot I_i \cdot Q_{i,t} + W_p \cdot P_i \cdot S_{i,t} + W_f \cdot (Q_{i,t} - S_{i,t})]}$$

Figure 1: Objective Function

By separating waste into three categories, unmet food waste, ingredient waste, and plate waste, this study seeks to reduce the overall cost of food waste in a hotel restaurant. Key cost factors are included in the function, including the cost of food that is made but not served, the cost of ingredients lost during preparation, and the cost of food that consumers leave uneaten. The model assesses the discrepancy between produced and served quantities for various meals and dishes using operational research methodologies. This method offers a methodical, data-driven framework to assist in making sustainable, reasonably priced food preparation choices in the face of erratic demand.

Constraints

1- **Serving Constraint:**

The quantity of prepared dishes should be greater or equal to the quantity served Also, the customer demand for prepared dishes should be greater or equal to the quantity served as well.

$$S_{i,t} \leq Q_{i,t}, \quad \forall i \in I,\ t \in T$$

$$S_{i,t} \leq D_{i,t}, \quad \forall i \in I,\ t \in T$$

Figure 2: Serving Constraint

The initial restriction makes sure that the amount served doesn't go over what was prepared or what the consumer wants. By avoiding overserving beyond actual supply or demand levels, this preserves feasibility and guarantees rational consistency in meal planning.

2- Monthly Kitchen Capacity Constraint:

Kitchen capacity limit at each meal period:

$$\boxed{\sum_{i \in I} Q_{i,t} \leq K_t, \quad \forall t \in T}$$

Figure 3: Monthly Kitchen Capacity Constraint

This restriction guarantees that the overall amount of resources used for every dish served during a mealtime stay is within the kitchen's capability. It keeps kitchen operations from being overloaded, allowing for reasonable and controllable production scheduling that considers staffing and equipment constraints.

3- Maximum Waste Rate Constraint:

$$\boxed{\frac{\sum_{i \in I} \left[(Q_{i,t} - S_{i,t}) + I_i \cdot Q_{i,t} + P_i \cdot S_{i,t} \right]}{\sum_{i \in I} Q_{i,t}} \leq r, \quad \forall t \in T}$$

Figure 4:Maximum Waste Rate Constraint

To guarantee that supply chain inefficiencies are reduced and sustainability goals are fulfilled, a maximum permissible percentage of unmet food demand, often referred to as acceptable food waste, is set.

4-Demand Coverage Constraint:

$$\boxed{\frac{\sum_{i \in I} S_{i,t}}{\sum_{i \in I} D_{i,t}} \geq \beta, \quad \forall t \in T}$$

Figure 5:Demand Covarage

To preserve customer satisfaction and guarantee that service level criteria are met, a predefined minimum proportion of the total customer demand must be met. In order to ensure that a minimum level of demand fulfillment is continuously met, this restriction is frequently included in operational and supply chain models. This supports company continuity and strengthens customer loyalty and trust.

5-Minimum Unmet Waste Constraint:

$$\boxed{Q_{i,t} \geq (1+\alpha) \cdot S_{i,t}, \quad \forall i \in I,\ t \in T}$$

Figure 6:Minimum Unmet Waste Constraint

This constraint posits that a negligible percentage of food may remain unmet within the system, primarily due to factors such as overproduction, spoilage, or logistical losses. This constraint acknowledges inherent inefficiencies in the restaurant.

(6) Non-negativity Constraint

$$\boxed{Q_{i,t} \geq 0, \quad S_{i,t} \geq 0, \quad \forall i \in I,\ t \in T}$$

Figure 7:Non-negativity Constraint

This restriction makes sure that the variables used to make decisions about serving and preparation amounts can't have negative values. It maintains the mathematical correctness of the optimization model and represents practicality, since negative food quantities have no practical significance.

Clear Explanation of Waste Components with Costs

Type of Waste	**Formula**	**Cost per Serving**
Unmet Food Waste	$(Q_{i,t} - S_{i,t})$	W_f
Ingredient Waste	$I_i \cdot Q_{i,t}$	W_i
Plate Waste	$P_i \cdot S_{i,t}$	W_p

Table 1:Waste Components with Costs

The chart lists the three main types of food waste and the related expenses for each. Meals that are cooked but not served to clients fall under the first type, known as unmet food waste, which directly costs money. The second is ingredient waste, which happens because of things like spoiling, spilling, or trimming during the preparation process. Finally, plate waste records the expense of food that is served but not eaten by patrons. By identifying and costing each type individually, the model provides a comprehensive structure to assess and minimize total food waste expenses in a hotel restaurant setting.

3.2 Literature Review

Here are the papers we have searched the web and found, and what we have learned from each paper. What we have learned from these papers helped us gain vision to how we build our model.

1. **Minimizing Waste in the Hospitality Industry: The Opportunities and Challenges of Lean Tourism**

Authors: Abdul Waaje, Rejaul Karim, Md. Mustaqim Roshid, Tamanna Nusrat Meem

This study explores the application of Lean principles, particularly 5S, Value Stream Mapping, and continuous improvement, in the hospitality sector to reduce operational waste. The authors highlight how adapting these manufacturing-based tools can improve service efficiency, sustainability, and guest satisfaction. A case study of the Ritz-Carlton in Riyadh demonstrates successful implementation.

2. **Operations Research in Hospitality Industry**

Authors: Harshil Mehta, Harshvardhan Mishra, Jay Shah, Jyotsna Singh, Khushi Fadia

This paper demonstrates the role of operations research tools such as linear programming, simulation models, assignment problems, and replacement models in solving real-world hospitality problems. It focuses on optimizing resource use, minimizing food waste, and improving service delivery. An example involving donut production is used to illustrate how OR improves decision-making in food production.

3. A Mathematical Optimization Model to Support Decision Making for Fast Food Enterprises

Authors: Jess S. Boronico, Alexandros Panayides, Lori Goldstein

The authors propose a mathematical optimization model to determine optimal shutdown times and preparation quantities in fast food businesses. The model helps reduce labor costs, leftover food, and missed sales opportunities. A real-life case study of a pretzel shop is used to validate the model, emphasizing its practical utility in inventory and labor management.

4. Demand Sensing for Restaurants Using Forecasting Methods

Author: Sidra Iqbal

This paper introduces a forecasting approach using Gradient Boosting Regression to accurately predict customer demand in restaurants. It features a user-friendly web application that supports dynamic inventory management. By improving forecasting accuracy, the model reduces food waste and enhances operational efficiency in restaurant settings.

5. Restaurant Sales and Customer Demand Forecasting: Literature Survey and Categorization of Methods

Authors: Elitsa A. Voynova, Kiril A. Tenekedjiev

This literature review categorizes various forecasting methods used in restaurants, such as regression analysis, neural networks, and hybrid models. It emphasizes the challenge of accurate demand forecasting due to the impact of external factors like holidays, local events, and weather. The paper provides comparative insights into which methods are best suited for complex, variable demand environments.

6. Food Waste in Hospitality and Food Services: A Systematic Literature Review and Framework Development Approach

Authors: Ceren Topal, Helen Rogers

Through a comprehensive literature review, this paper identifies major sources of food waste in hospitality, such as poor menu planning, incorrect portion sizes, and weak demand forecasting. It develops a conceptual framework linking these factors and provides managerial strategies to mitigate them. The study supports sustainable and efficient food service practices.

7. Food Waste in Hotel Restaurants: Causes, Reducing Practices and Barriers

Authors: Shaila Jamal, A.A.M. Faizul Haque

This study investigates the key drivers of food waste in hotel restaurants, focusing on buffet systems, overproduction, and flawed demand forecasting. It also identifies obstacles to waste reduction, such as lack of staff training and poor planning. The authors suggest effective waste reduction strategies including portion control, menu design, and enhanced inventory practices.

8. Combating Food Waste by Supply Chain Modelling and Optimization

Authors: René Haijema and colleagues (Wageningen University & Research)

The important problem of food waste in European retail, especially supermarkets, is the focus of this study, which was carried out as part of the EU REFRESH project. According to the report, one of the main causes of waste is mismatches between supply and demand, particularly for perishable goods. To address this, the researchers created mathematical models that included real-time quality evaluations and dynamically configurable expiration dates. Retailers can use these models to modify price and inventory choices in accordance with the products' actual shelf lives. The study shows how these models may be included in inventory management systems to reduce food waste while preserving service quality and financial success. The results highlight how integrating cutting-edge modeling methods with realistic retail tactics might improve food supply chain sustainability.

9. An Optimization Approach for Food Waste Management System Based on Multi-Objective Programming

This study offers a thorough optimization model for managing food waste that considers social, economic, environmental, and energy goals all at once. To balance these frequently conflicting objectives, the model uses multi-objective programming, giving decision-makers a framework for creating effective and long-lasting food waste management systems. The model assists in determining the best practices that maximize energy recovery and social benefits while minimizing expenses and environmental effect by combining many criteria. The study emphasizes the value of managing food waste holistically and acknowledges the connections between many societal objectives.

10. Minimizing Food Waste in Grocery Store Operations

Authors: L. Riesenegger, J. Hübner, and colleagues

This study examines methods for optimizing assortment planning, replenishment procedures, and dynamic pricing to reduce food waste in grocery store operations. The authors examine how the complexity of inventory management can result in greater waste when product assortments are expanded. They suggest dynamic pricing techniques to sell products that are about to expire, as well as customized replenishment methods that consider client demand trends and product shelf life. To successfully reduce food waste and enhance sustainability in retail settings, the study highlights the necessity of integrated planning across several operational domains.

11. A Location-Allocation Model for Bio-Waste Management in the Hospitality Sector

Authors: Dolores R. Santos-Peñate, Rafael R. Suárez-Vega, Carmen Florido de la Nuez

With an emphasis on hotel chains, this study presents a mathematical optimization model for managing bio-waste in the hospitality sector. The methodology tackles the challenge of identifying facilities for composting and pelletizing food and garden waste produced by hotels. To promote a circular economy where trash is transformed into valuable goods like compost and pellets, the model seeks to minimize transportation costs and environmental impact by strategically placing and allocating these facilities. By effectively managing bio-waste, the study gives hotel companies a useful tool to improve their sustainability efforts.

12. A Mathematical Model of Waste Management and Food Loss Along the Agrifood Chain

Authors: Nicolae Nijloveanu, et al.

Food loss and waste (FLW) phenomena are simulated and analyzed using Petri nets in this study's mathematical model for waste management in the agrifood chain. To identify and optimize processes associated with food product production, processing, distribution, and consumption, the model provides a distributed systems approach. The study illustrates the potential of Petri nets in modeling intricate food supply chains and offers insights into efficient waste management techniques by simulating a variety of scenarios.

13. Stochastic Mathematical Model for Food Waste Reduction in a Two-Level Supply Chain for Highly Perishable Products

Author: Po-ngarm Somkun

To reduce food waste in a two-level supply chain that involves merchants and consumers, this article presents a stochastic mathematical model. The model, which focuses on extremely perishable goods with a one-day shelf life, takes into consideration consumer demand and consumption trends in addition to merchants' inventory replenishment procedures. Using probabilistic components and modeling different inventory regulations, the study finds the best ways to reduce food loss throughout the supply chain.

14. Mathematical Model for Optimal Agri-Food Industry Residual Streams Flow Management: A Valorization Decision Support Tool

Authors: Íñigo Barasoain-Echepare, Marta Zárraga -Rodríguez, et al.

An optimization-based decision support tool for residual stream management in the agri-food sector is presented by the authors. Based on cost-benefit assessments, the mathematical model determines which waste valorization pathways, like composting or bioenergy production, are most advantageous. By reducing waste disposal and increasing resource reuse, the model improves sustainability and offers a useful implementation of circular economic concepts in food systems.

15. Optimization Approaches for Modeling Food Waste Management Systems

This study explores the ways in which food waste collection and treatment systems might be enhanced through optimization strategies. By selecting the optimal facility sites, routes, and processing alternatives for collected food waste, it offers a mathematical model that reduces expenses. The model shows how systems design can directly affect the efficacy of food waste reduction by accounting for transportation, operating, and environmental costs.

16. Combating Food Waste by Supply Chain Modelling and Optimization

Authors: René Haijema and colleagues (Wageningen University & Research)

By simulating supply chain modifications including shelf-life-based pricing and expiration tracking, this study tackles food waste. Dynamic inventory models that adjust to current product quality are suggested by the researchers. When applied to retail environments in Europe, the concept increased profitability and decreased waste. The results highlight how sustainable food supply chain management is achieved by fusing digital tools and optimization methodologies.

Chapter 4 Design and Solution Approach

4.1 Applied Solution

---- 108 VARIABLE Q.L Quantity prepared

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	39.600	40.800	44.400	43.200	44.400	48.000	50.400	54.000	55.200	55.200	45.600	38.400
i2	16.800	15.600	18.000	18.000	15.600	15.600	26.400	22.800	21.600	22.800	19.200	16.800
i3	37.200	40.800	43.200	39.600	43.200	44.400	55.200	49.200	48.000	49.200	44.400	34.800
i5	32.400	36.000	34.800	34.800	32.400	31.200	38.400	43.200	45.600	45.600	36.000	31.200
i6	16.800	16.800	16.800	18.000	19.200	16.800	27.600	22.800	26.400	27.600	15.600	16.800
i7	31.200	31.200	28.800	33.600	37.200	40.800	43.200	42.000	45.600	45.600	30.000	30.000
i8	27.600	28.800	31.200	30.000	33.600	32.400	40.800	37.200	37.200	39.600	26.400	26.400
i9	32.400	36.000	38.400	34.800	34.800	37.200	43.200	43.200	40.800	43.200	37.200	31.200
i10	46.800	45.600	49.200	50.400	50.400	49.200	55.200	62.400	62.400	64.800	50.400	44.400
i11	32.400	33.600	31.200	34.800	36.000	33.600	36.000	43.200	40.800	42.000	26.400	31.200
i12	46.800	49.200	48.000	50.400	55.200	56.400	60.000	62.400	61.200	60.000	49.200	44.400
i13	44.400	45.600	49.200	48.000	52.800	56.400	56.400	60.000	62.400	60.000	49.200	42.000
i14	24.000	27.600	30.000	25.200	28.800	31.200	39.600	31.200	28.800	30.000	27.600	22.800
i15	21.600	24.000	27.600	22.800	24.000	24.000	30.000	28.800	30.000	30.000	26.400	20.400
i17	54.000	57.600	61.200	58.800	62.400	66.000	75.600	73.200	70.800	73.200	60.000	51.600
i18	44.400	48.000	48.000	48.000	50.400	52.800	56.400	60.000	62.400	61.200	46.800	42.000
i19	33.600	32.400	34.800	36.000	40.800	43.200	54.000	44.400	42.000	44.400	32.400	32.400
i22	36.000	34.800	38.400	38.400	36.000	39.600	42.000	48.000	49.200	48.000	39.600	33.600
i23	21.600	22.800	25.200	22.800	25.200	27.600	33.600	28.800	31.200	33.600	20.400	20.400
i24	37.200	38.400	42.000	40.800	40.800	38.400	39.600	50.400	48.000	50.400	37.200	36.000
i25	51.600	52.800	54.000	56.400	61.200	64.800	74.400	69.600	69.600	69.600	51.600	49.200
i26	5.400	7.020	4.920	6.240	10.020	4.920	0.600	6.180	4.800	8.040	4.740	4.800
i27	43.200	45.600	43.200	46.800	49.200	50.400	51.600	57.600	61.200	60.000	38.400	40.800
i28	36.000	38.400	36.000	38.400	40.800	39.600	42.000	48.000	48.000	45.600	37.200	33.600
i29	49.200	52.800	56.400	54.000	51.600	52.800	57.600	67.200	67.200	68.400	57.600	48.000
i30	43.200	46.800	44.400	46.800	49.200	48.000	51.600	57.600	61.200	58.800	43.200	40.800
i31	21.600	21.600	25.200	22.800	26.400	24.000	26.400	28.800	27.600	27.600	21.600	20.400
i33	49.200	48.000	46.800	52.800	56.400	58.800	61.200	66.000	69.600	69.600	44.400	46.800
i34	18.000	20.400	24.000	19.200	19.200	18.000	21.600	24.000	21.600	24.000	20.400	16.800
i35	26.400	26.400	28.800	28.800	31.200	31.200	42.000	36.000	37.200	39.600	27.600	25.200
i36	18.000	15.600	16.800	19.200	19.200	20.400	27.600	24.000	24.000	26.400	15.600	16.800
i37	28.800	30.000	31.200	31.200	28.800	31.200	31.200	38.400	42.000	42.000	27.600	27.600
i38	33.600	34.800	38.400	36.000	39.600	39.600	49.200	44.400	42.000	43.200	34.800	32.400
i39	54.000	52.800	51.600	58.800	58.800	56.400	55.200	73.200	76.800	74.400	49.200	51.600
i40	38.400	42.000	43.200	42.000	45.600	45.600	45.600	52.800	51.600	52.800	40.800	37.200
i42	22.800	20.400	20.400	24.000	27.600	25.200	26.400	30.000	32.400	32.400	15.600	21.600
i43	26.400	30.000	33.600	28.800	27.600	30.000	37.200	36.000	38.400	36.000	34.800	25.200
i44	25.200	26.400	26.400	27.600	31.200	32.400	33.600	34.800	37.200	39.600	25.200	25.200
i45	22.800	22.800	21.600	24.000	25.200	27.600	38.400	30.000	32.400	32.400	19.200	21.600
i46	32.400	33.600	31.200	34.800	33.600	33.600	32.400	43.200	44.400	45.600	27.600	31.200
i47	51.600	50.400	54.000	56.400	54.000	57.600	68.400	69.600	67.200	66.000	55.200	49.200
i48	19.200	18.000	15.600	20.400	25.200	22.800	24.000	25.200	27.600	26.400	10.800	18.000
i49	27.600	27.600	26.400	30.000	33.600	37.200	39.600	37.200	34.800	33.600	21.600	26.400
i50	36.000	34.800	32.400	38.400	40.800	44.400	45.600	48.000	46.800	49.200	28.800	33.600
i51	43.200	44.400	43.200	46.800	45.600	45.600	56.400	57.600	57.600	56.400	38.400	40.800
i52	33.600	32.400	33.600	36.000	40.800	43.200	44.400	44.400	44.400	46.800	31.200	32.400

Table 2:Data Table 1

---- 108 VARIABLE S.L Quantity served

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	33.000	34.000	37.000	36.000	37.000	40.000	42.000	45.000	46.000	46.000	38.000	32.000
i2	14.000	13.000	15.000	15.000	13.000	13.000	22.000	19.000	18.000	19.000	16.000	14.000
i3	31.000	34.000	36.000	33.000	36.000	37.000	46.000	41.000	40.000	41.000	37.000	29.000
i5	27.000	30.000	29.000	29.000	27.000	26.000	32.000	36.000	38.000	38.000	30.000	26.000
i6	14.000	14.000	14.000	15.000	16.000	14.000	23.000	19.000	22.000	23.000	13.000	14.000
i7	26.000	26.000	24.000	28.000	31.000	34.000	36.000	35.000	38.000	38.000	25.000	25.000
i8	23.000	24.000	26.000	25.000	28.000	27.000	34.000	31.000	31.000	33.000	22.000	22.000
i9	27.000	30.000	32.000	29.000	29.000	31.000	36.000	36.000	34.000	36.000	31.000	26.000
i10	39.000	38.000	41.000	42.000	42.000	41.000	46.000	52.000	52.000	54.000	42.000	37.000
i11	27.000	28.000	26.000	29.000	30.000	28.000	30.000	36.000	34.000	35.000	22.000	26.000
i12	39.000	41.000	40.000	42.000	46.000	47.000	50.000	52.000	51.000	50.000	41.000	37.000
i13	37.000	38.000	41.000	40.000	44.000	47.000	47.000	50.000	52.000	50.000	41.000	35.000
i14	20.000	23.000	25.000	21.000	24.000	26.000	33.000	26.000	24.000	25.000	23.000	19.000
i15	18.000	20.000	23.000	19.000	20.000	20.000	25.000	24.000	25.000	25.000	22.000	17.000
i17	45.000	48.000	51.000	49.000	52.000	55.000	63.000	61.000	59.000	61.000	50.000	43.000
i18	37.000	40.000	40.000	40.000	42.000	44.000	47.000	50.000	52.000	51.000	39.000	35.000
i19	28.000	27.000	29.000	30.000	34.000	36.000	45.000	37.000	35.000	37.000	27.000	27.000
i22	30.000	29.000	32.000	32.000	30.000	33.000	35.000	40.000	41.000	40.000	33.000	28.000
i23	18.000	19.000	21.000	19.000	21.000	23.000	28.000	24.000	26.000	28.000	17.000	17.000
i24	31.000	32.000	35.000	34.000	34.000	32.000	33.000	42.000	40.000	42.000	31.000	30.000
i25	43.000	44.000	45.000	47.000	51.000	54.000	62.000	58.000	58.000	58.000	43.000	41.000
i26	4.500	5.850	4.100	5.200	8.350	4.100	0.500	5.150	4.000	6.700	3.950	4.000
i27	36.000	38.000	36.000	39.000	41.000	42.000	43.000	48.000	51.000	50.000	32.000	34.000
i28	30.000	32.000	30.000	32.000	34.000	33.000	35.000	40.000	40.000	38.000	31.000	28.000
i29	41.000	44.000	47.000	45.000	43.000	44.000	48.000	56.000	56.000	57.000	48.000	40.000
i30	36.000	39.000	37.000	39.000	41.000	40.000	43.000	48.000	51.000	49.000	36.000	34.000
i31	18.000	18.000	21.000	19.000	22.000	20.000	22.000	24.000	23.000	23.000	18.000	17.000
i33	41.000	40.000	39.000	44.000	47.000	49.000	51.000	55.000	58.000	58.000	37.000	39.000
i34	15.000	17.000	20.000	16.000	16.000	15.000	18.000	20.000	18.000	20.000	17.000	14.000
i35	22.000	22.000	24.000	24.000	26.000	26.000	35.000	30.000	31.000	33.000	23.000	21.000
i36	15.000	13.000	14.000	16.000	16.000	17.000	23.000	20.000	20.000	22.000	13.000	14.000
i37	24.000	25.000	26.000	26.000	24.000	26.000	26.000	32.000	35.000	35.000	23.000	23.000
i38	28.000	29.000	32.000	30.000	33.000	33.000	41.000	37.000	35.000	36.000	29.000	27.000
i39	45.000	44.000	43.000	49.000	49.000	47.000	46.000	61.000	64.000	62.000	41.000	43.000
i40	32.000	35.000	36.000	35.000	38.000	38.000	38.000	44.000	43.000	44.000	34.000	31.000
i42	19.000	17.000	17.000	20.000	23.000	21.000	22.000	25.000	27.000	27.000	13.000	18.000
i43	22.000	25.000	28.000	24.000	23.000	25.000	31.000	30.000	32.000	30.000	29.000	21.000
i44	21.000	22.000	22.000	23.000	26.000	27.000	28.000	29.000	31.000	33.000	21.000	21.000
i45	19.000	19.000	18.000	20.000	21.000	23.000	32.000	25.000	27.000	27.000	16.000	18.000
i46	27.000	28.000	26.000	29.000	28.000	28.000	27.000	36.000	37.000	38.000	23.000	26.000
i47	43.000	42.000	45.000	47.000	45.000	48.000	57.000	58.000	56.000	55.000	46.000	41.000
i48	16.000	15.000	13.000	17.000	21.000	19.000	20.000	21.000	23.000	22.000	9.000	15.000
i49	23.000	23.000	22.000	25.000	28.000	31.000	33.000	31.000	29.000	28.000	18.000	22.000
i50	30.000	29.000	27.000	32.000	34.000	37.000	38.000	40.000	39.000	41.000	24.000	28.000
i51	36.000	37.000	36.000	39.000	38.000	38.000	47.000	48.000	48.000	47.000	32.000	34.000
i52	28.000	27.000	28.000	30.000	34.000	36.000	37.000	37.000	37.000	39.000	26.000	27.000

Table 3:Data Table 2

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----    108 VARIABLE Z.L                   =  3445225.317  Total waste cost
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In this revised scenario, a larger dataset of 152 dishes (i1–i152) across 12 months (t1–t12) was used to run the GAMS optimization model. The findings show that the best preparation quantities (Q.L.) and service quantities (S.L.) are those that are designed to reduce overall food waste expenses while meeting anticipated demand and operational limitations. Compared to the previously recorded cost of 2,539,688.98 TL, the output shows a total waste cost of 3,445,225.317 TL, which is far higher. The inclusion of additional dishes, each with its own waste factors, perishability profiles, and preparation inefficiencies, is probably the cause of this increase. When Q(i,t) and S(i,t) matrices are compared, it is evident that there is a significant amount of unmet food waste for many dishes due to the persistent gap between preparation and service quantities. Three waste components, unmet food waste, ingredient waste, and plate waste are still taken into consideration by the cost function. Each is weighted by dish-specific coefficients that are obtained from operational data. The new findings highlight the need to strike a balance between client demand and production volume, particularly when expanding to a broader menu. The higher price also highlights how difficult it is to manage food resources across a dynamic and varied menu, underscoring the importance of data-driven optimization in hospitality operations.

- Here is the waste percentage for each month and we have found the results of August, Septemper and October has the highest percentage of wasted amount of food.

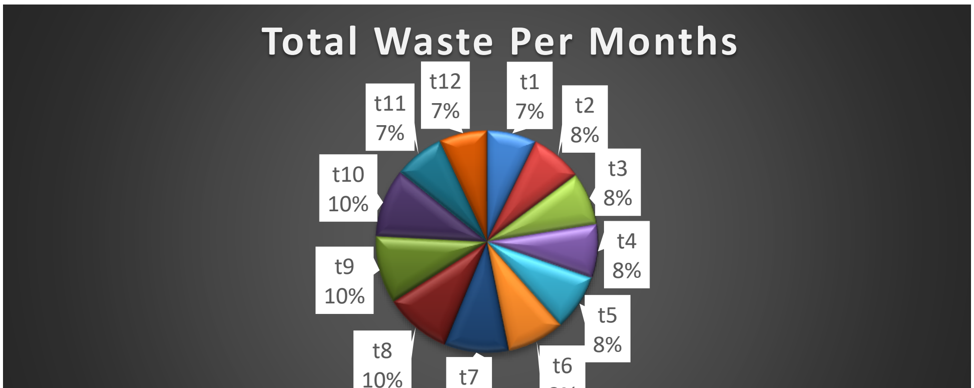
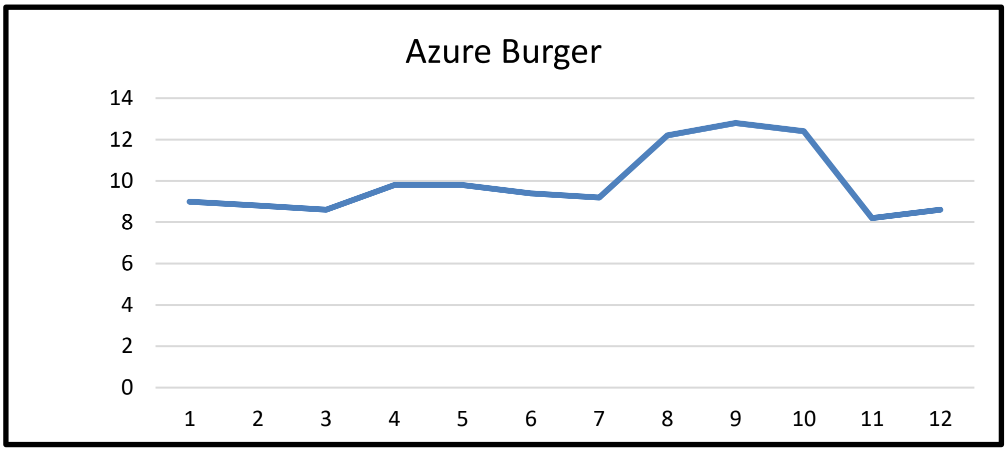
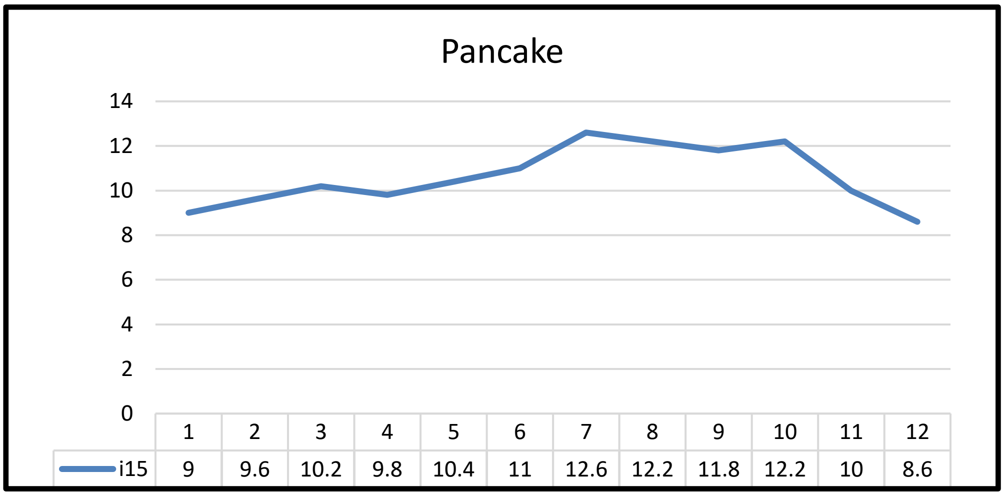
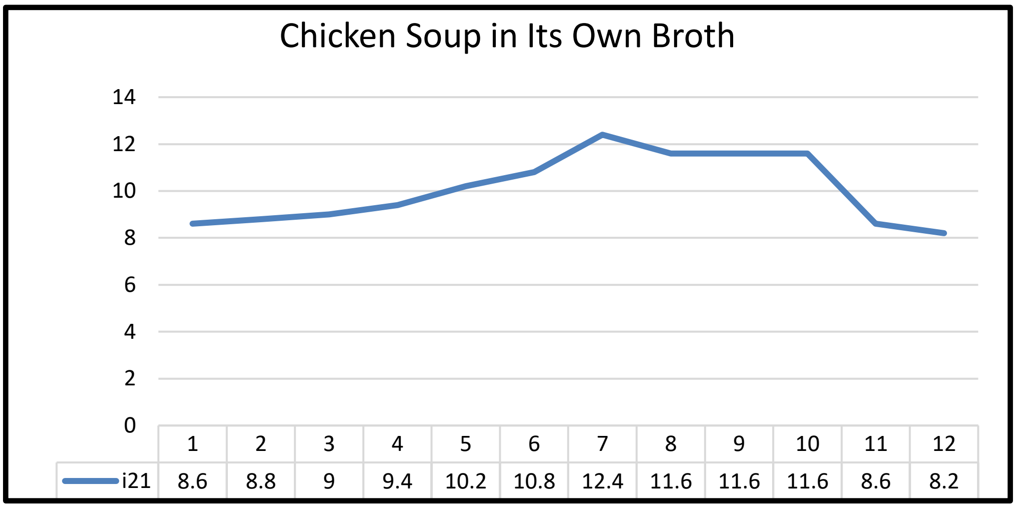


Figure 8: Total Waste per Months

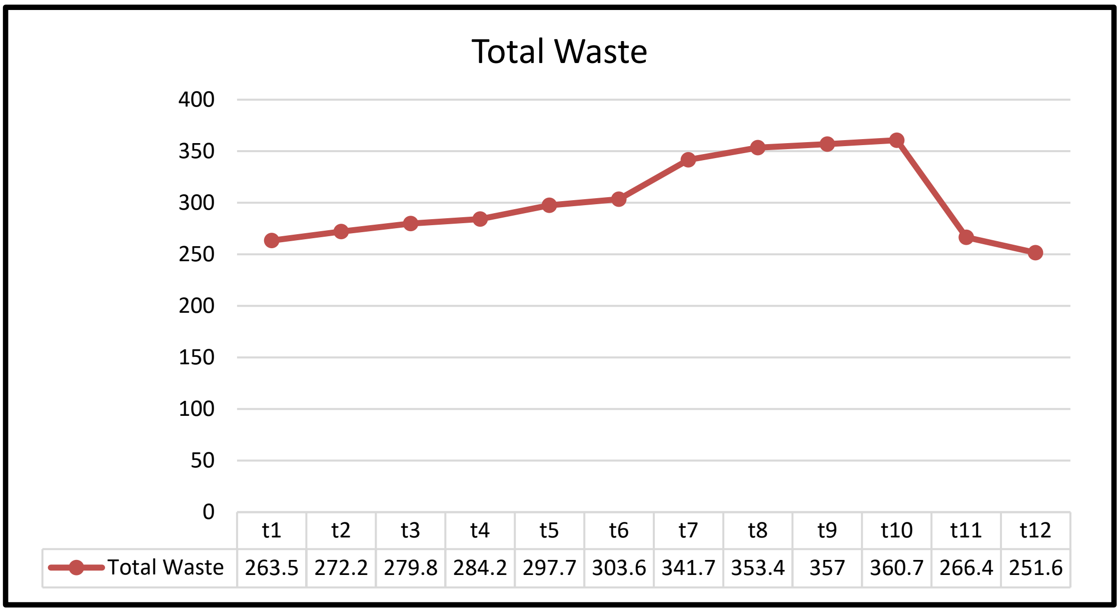
And we found three dishes which have the most waste food and less demand.



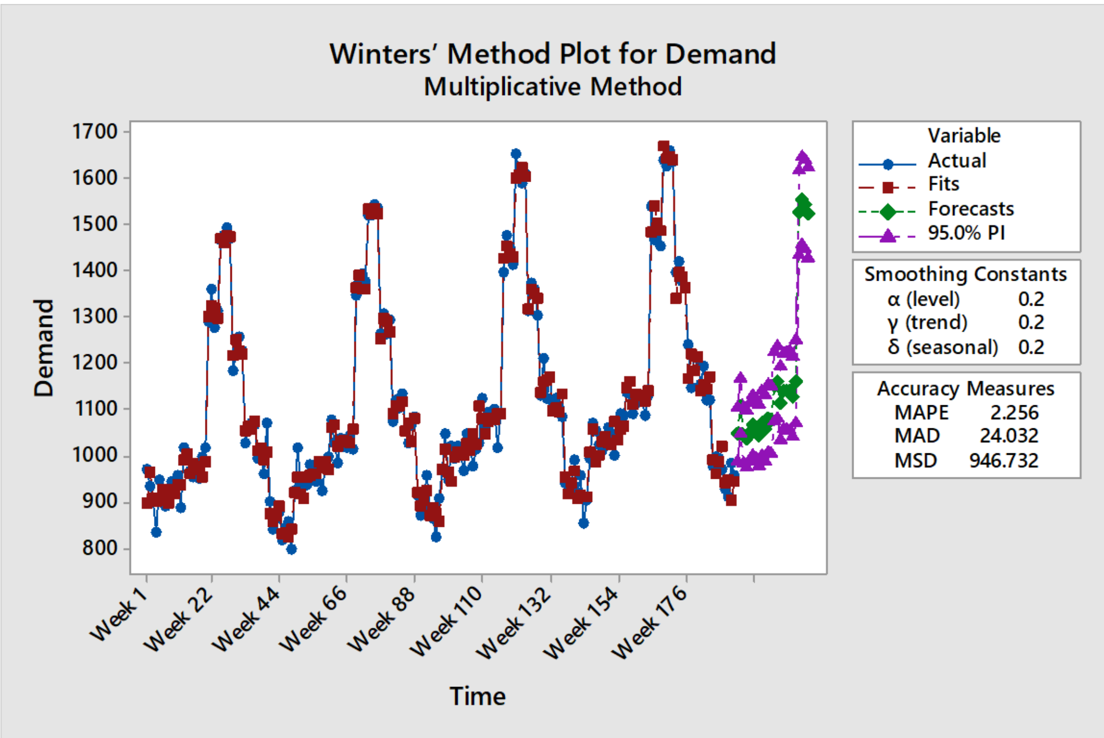




We have displayed the total cost every month which have the unmet waste food which is Q – S as you can see in the figure below:



Applying Winter's Forecasting Method:



Forecasts

Period	Forecast	Lower	Upper
193	1046.54	987.66	1105.42
194	1107.62	1047.82	1167.42
195	1043.92	983.09	1104.75
196	1036.07	974.12	1098.03
197	1050.55	987.37	1113.74
198	1066.14	1001.65	1130.64
199	1058.86	992.97	1124.76
200	1044.03	976.66	1111.41
201	1070.96	1002.03	1139.89
202	1058.47	987.92	1129.02
203	1080.12	1007.88	1152.35
204	1077.96	1003.98	1151.94
205	1148.87	1073.08	1224.66
206	1159.04	1081.40	1236.69
207	1112.68	1033.13	1192.22
208	1139.28	1057.78	1220.77
209	1141.20	1057.72	1224.69
210	1140.37	1054.86	1225.89
211	1126.86	1039.28	1214.44
212	1160.77	1071.09	1250.45
213	1525.72	1433.91	1617.53
214	1551.60	1457.63	1645.57
215	1542.00	1445.84	1638.16
216	1523.29	1424.92	1621.67

4.2 Data Structure

The following data presents the monthly customer demand figures for 92 distinct dishes served at Azure Bosphorus Restaurant, covering a continuous 12-month period. This comprehensive data collection reflects the seasonal variation in customer preferences and serves as a foundational input for subsequent modeling and analysis tasks, including forecasting, inventory planning, and food waste minimization strategies within the restaurant's operations.

Table 4 Demand Data

D	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
Make Your Own Omelette	33	34	37	36	37	40	42	45	46	46	38	32
Flatbread Toast	14	13	15	15	13	13	22	19	18	19	16	14
Egg with Sucuk	31	34	36	33	36	37	46	41	40	41	37	29
Turkish Breakfast Platter	20	21	21	21	24	24	24	26	28	29	21	19
Azure Mixed Toast	27	30	29	29	27	26	32	36	38	38	30	26
Good Morning Beyoğlu	14	14	14	15	16	14	23	19	22	23	13	14
Scrambled Avocado	26	26	24	28	31	34	36	35	38	38	25	25
Cheese Toast	23	24	26	25	28	27	34	31	31	33	22	22
Cornmeal with Cheese and Butter	27	30	32	29	29	31	36	36	34	36	31	26
Spinach and Cheese Fritters	39	38	41	42	42	41	46	52	52	54	42	37
Omelette Varieties	27	28	26	29	30	28	30	36	34	35	22	26
Menemen	39	41	40	42	46	47	50	52	51	50	41	37
Fried Egg in a Pan	37	38	41	40	44	47	47	50	52	50	41	35
Truffle Oil	20	23	25	21	24	26	33	26	24	25	23	19
Pancake	18	20	23	19	20	20	25	24	25	25	22	17
Plain Fried Potatoes	36	38	38	39	43	46	53	48	48	50	35	34
Greek Salad	45	48	51	49	52	55	63	61	59	61	50	43
Caprese Salad	37	40	40	40	42	44	47	50	52	51	39	35
Grain Bowl	28	27	29	30	34	36	45	37	35	37	27	27
Seasonal Fruit Acai Bowl	38	40	43	41	44	42	42	51	51	49	39	36
Chicken Soup in Its Own Broth	46	49	49	50	53	53	57	62	61	63	48	44

Avocado Hummus	30	29	32	32	30	33	35	40	41	40	33	28
Crispy Chicken	18	19	21	19	21	23	28	24	26	28	17	17
Chicken Taco	31	32	35	34	34	32	33	42	40	42	31	30
Cherry Leaf Wrap	43	44	45	47	51	54	62	58	58	58	43	41
Mozzarella Stick	35	35	35	38	41	42	51	47	45	47	33	34
Azure Delight Plate	36	38	36	39	41	42	43	48	51	50	32	34
Chicken Caesar Salad	30	32	30	32	34	33	35	40	40	38	31	28
Spicy-Sour Chicken Bowl	41	44	47	45	43	44	48	56	56	57	48	40
Hamburger	36	39	37	39	41	40	43	48	51	49	36	34
Cheeseburger	18	18	21	19	22	20	22	24	23	23	18	17
Double Burger	24	22	23	26	26	26	29	32	33	33	24	23
Tavuk Burger	41	40	39	44	47	49	51	55	58	58	37	39
Azure Burger	15	17	20	16	16	15	18	20	18	20	17	14
Çıtır Tavuk Burger	22	22	24	24	26	26	35	30	31	33	23	21
Mini Burger	15	13	14	16	16	17	23	20	20	22	13	14
Mexican Burger	24	25	26	26	24	26	26	32	35	35	23	23
Fettuccine Parmesan Wheel	28	29	32	30	33	33	41	37	35	36	29	27
Penne Al'Arabiatta	45	44	43	49	49	47	46	61	64	62	41	43
Azure Manti	32	35	36	35	38	38	38	44	43	44	34	31
Spaghetti Bolognese	38	41	42	41	40	39	46	51	53	54	39	36
Five-Cheese Ravioli	19	17	17	20	23	21	22	25	27	27	13	18
Paccheri with Mushrooms and Shrimp	22	25	28	24	23	25	31	30	32	30	29	21

Fettuccine Alfredo with Chicken	21	22	22	23	26	27	28	29	31	33	21	21
Tai Chili Tenderloin	19	19	18	20	21	23	32	25	27	27	16	18
Lasagna	27	28	26	29	28	28	27	36	37	38	23	26
Rigatoni with Burrata	43	42	45	47	45	48	57	58	56	55	46	41
Chicken Noodles	16	15	13	17	21	19	20	21	23	22	9	15
Cheese Crispy Chicken Meatballs	23	23	22	25	28	31	33	31	29	28	18	22
Chicken Caesar Salad	30	29	27	32	34	37	38	40	39	41	24	28
Grilled Chicken Halloumi Skewer	36	37	36	39	38	38	47	48	48	47	32	34
Lentil Soup with Meat Broth	28	27	28	30	34	36	37	37	37	39	26	27
Smoked Salmon Bruschetta	21	22	22	23	21	19	23	29	30	30	23	21
Burrata	18	21	24	19	21	24	29	24	24	23	23	17
Raw Meatless Köfte Rolls	45	43	43	49	53	53	59	61	61	59	41	43
Shrimp Taco	31	30	33	34	32	34	36	42	42	40	31	30
Fish and Chips	39	38	37	42	40	41	43	52	55	57	33	37
Fried Calamari	39	38	40	42	43	44	53	52	53	54	41	37
Spoon Fried Potatoes	34	33	36	37	38	40	44	46	44	44	36	33
Azure Orange-Smoked	40	42	41	43	42	43	50	53	51	51	42	38
Shrimp-Avocado Salad	23	24	23	25	26	27	28	31	30	28	19	22
Salmon & Avocado Bowl	16	18	17	17	21	24	29	21	23	25	18	15
Suziki Roll	36	39	39	39	37	36	38	48	50	50	40	34
Boston Roll	38	37	35	41	42	44	48	51	50	51	31	36
Philadelphia Roll	17	18	17	18	21	21	25	23	26	27	15	16

California Roll	18	18	17	19	21	19	21	24	27	29	14	17
Suziki Nigiri	33	32	31	36	37	35	35	45	48	48	31	32
Somon Nigiri	36	35	37	39	42	44	45	48	51	51	33	34
Konikama Nigiri	22	21	19	24	23	26	35	30	32	33	17	21
Futo Maki	15	13	15	16	18	18	18	20	23	21	15	14
Sake Maki	41	43	42	45	47	46	50	56	59	60	39	40
Suziki Maki	16	17	15	17	18	16	25	21	24	26	14	15
Azure Roll	25	27	29	27	28	29	35	34	33	34	29	24
Margherita Pizza	40	42	40	43	42	41	46	53	56	58	38	38
Alaturka Pizza	19	22	24	20	24	27	36	25	28	26	24	18
Truffle Pizza	22	22	24	24	26	25	31	30	33	32	20	21
Azure Pizza	14	14	14	15	19	20	28	19	22	24	11	14
Chicken Mexican Pizza	19	22	23	20	21	19	26	25	23	22	24	18
Burrata Pizza	21	22	24	23	24	24	33	29	30	31	24	21
Four-Cheese Pizza	25	27	30	27	31	31	39	34	37	37	26	24
Kokoreç	42	40	39	46	50	53	57	57	58	58	37	41
Buttered Leaf Iskender	41	44	47	45	44	43	51	56	58	60	45	40
Azure Gentle Kebab	21	23	23	22	23	23	28	28	27	25	22	20
Beef Stroganoff	31	34	34	34	33	35	35	42	40	42	30	30
Lamb Shoulder Tandoor	24	25	24	26	28	30	35	32	31	33	20	23
Teriyaki Beef Ribs	40	38	41	43	47	45	52	53	54	56	38	38
New York Steak	26	24	24	28	31	31	33	35	38	37	23	25
Grilled Meatballs	20	21	19	21	19	22	22	26	27	28	16	19
Azure Society Kebab	43	45	46	47	47	47	47	58	56	54	46	41

Meat-filled Leaf Wrap	45	48	48	49	47	45	51	61	60	58	46	43
Grilled Salmon	36	37	40	39	38	39	46	48	48	48	38	34
Grilled Sea Bass	43	46	44	47	48	51	50	58	59	59	40	41

Table 5 Ii : Ingredient waste factor for dish i (wasted during preparation), Pi : Plate waste factor for dish i (uneaten by customers), Wi : Cost per serving of ingredient waste (waste during preparation), Wp : Cost per serving of plate waste (uneaten portions), Wf : Cost per serving of unmet food waste (prepared but not served). The dataset also includes critical parameters associated with food waste and cost efficiency, specifically: the Ingredient Waste Factor, Plate Waste Factor, the unit cost incurred per serving of ingredient waste, the unit cost per serving of plate waste, and the unit cost associated with unmet food waste. These variables are essential for quantifying the economic and environmental impact of inefficiencies in food preparation, service, and demand fulfillment. Collectively, they serve as key inputs for developing optimization models aimed at minimizing total food waste within the operational framework of Azure Bosphorus Restaurant.

Ii		Pi		Wi		Wp		Wf	
i1	0,05	i1	0,10	i1	120	i1	395	i1	395
i2	0,12	i2	0,13	i2	85	i2	415	i2	415
i3	0,13	i3	0,14	i3	285	i3	375	i3	375
i4	0,15	i4	0,11	i4	370	i4	1590	i4	1590
i5	0,08	i5	0,11	i5	300	i5	395	i5	395
i6	0,06	i6	0,09	i6	850	i6	475	i6	475
i7	0,14	i7	0,08	i7	865	i7	365	i7	365
i8	0,09	i8	0,10	i8	780	i8	355	i8	355
i9	0,06	i9	0,08	i9	720	i9	385	i9	385
i10	0,22	i10	0,09	i10	220	i10	290	i10	290

i11	0,06	i11	0,12	i11	250	i11	275	i11	275
i12	0,22	i12	0,07	i12	670	i12	315	i12	315
i13	0,05	i13	0,12	i13	500	i13	215	i13	215
i14	0,17	i14	0,08	i14	200	i14	365	i14	365
i15	0,13	i15	0,11	i15	430	i15	445	i15	445
i16	0,23	i16	0,10	i16	800	i16	440	i16	440
i17	0,13	i17	0,10	i17	107	i17	560	i17	560
i18	0,07	i18	0,06	i18	18	i18	520	i18	520
i19	0,13	i19	0,10	i19	43	i19	570	i19	570
i20	0,14	i20	0,07	i20	1500	i20	619	i20	619
i21	0,15	i21	0,12	i21	1200	i21	275	i21	275
i22	0,03	i22	0,10	i22	52	i22	345	i22	345
i23	0,05	i23	0,08	i23	90	i23	670	i23	670
i24	0,15	i24	0,10	i24	170	i24	560	i24	560
i25	0,07	i25	0,09	i25	340	i25	365	i25	365
i26	0,19	i26	0,11	i26	525	i26	565	i26	565
i27	0,03	i27	0,15	i27	300	i27	780	i27	780
i28	0,15	i28	0,10	i28	46	i28	555	i28	555
i29	0,1	i29	0,11	i29	63	i29	620	i29	620
i30	0,04	i30	0,08	i30	195	i30	655	i30	655
i31	0,12	i31	0,11	i31	100	i31	685	i31	685
i32	0,22	i32	0,11	i32	71	i32	985	i32	985
i33	0,22	i33	0,10	i33	233	i33	585	i33	585
i34	0,07	i34	0,11	i34	24	i34	695	i34	695
i35	0,04	i35	0,09	i35	200	i35	615	i35	615
i36	0,05	i36	0,10	i36	373	i36	645	i36	645

i37	0,03	i37	0,12	i37	41	i37	680	i37	680
i38	0,15	i38	0,10	i38	190	i38	850	i38	850
i39	0,17	i39	0,14	i39	22	i39	490	i39	490
i40	0,22	i40	0,10	i40	270	i40	520	i40	520
i41	0,2	i41	0,09	i41	900	i41	539	i41	539
i42	0,08	i42	0,11	i42	170	i42	619	i42	619
i43	0,15	i43	0,07	i43	39	i43	768	i43	768
i44	0,07	i44	0,09	i44	90	i44	639	i44	639
i45	0,05	i45	0,12	i45	270	i45	659	i45	659
i46	0,1	i46	0,10	i46	28	i46	539	i46	539
i47	0,21	i47	0,08	i47	380	i47	619	i47	619
i48	0,16	i48	0,12	i48	410	i48	619	i48	619
i49	0,13	i49	0,09	i49	130	i49	575	i49	575
i50	0,15	i50	0,11	i50	85	i50	555	i50	555
i51	0,15	i51	0,13	i51	65	i51	719	i51	719
i52	0,15	i52	0,13	i52	60	i52	240	i52	240
i53	0,1	i53	0,09	i53	155	i53	525	i53	525
i54	0,03	i54	0,11	i54	700	i54	595	i54	595
i55	0,06	i55	0,12	i55	800	i55	395	i55	395
i56	0,19	i56	0,15	i56	29	i56	659	i56	659
i57	0,19	i57	0,10	i57	36	i57	660	i57	660
i58	0,03	i58	0,11	i58	275	i58	675	i58	675
i59	0,1	i59	0,09	i59	90	i59	460	i59	460
i60	0,19	i60	0,11	i60	170	i60	615	i60	615
i61	0,12	i61	0,10	i61	380	i61	649	i61	649
i62	0,08	i62	0,06	i62	250	i62	679	i62	679

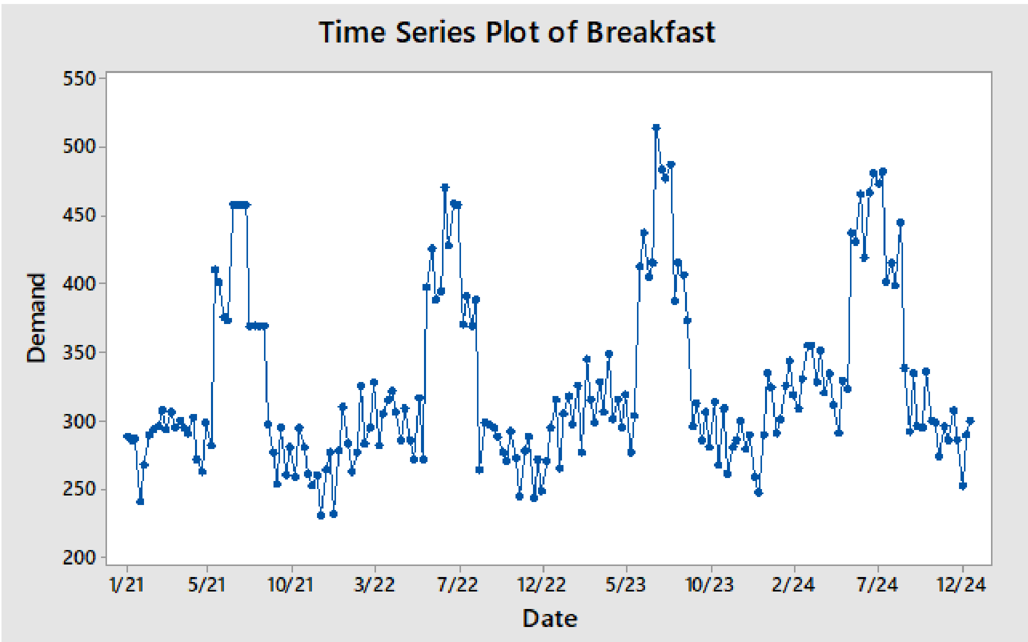
i63	0,09	i63	0,10	i63	120	i63	775	i63	775
i64	0,2	i64	0,12	i64	145	i64	789	i64	789
i65	0,14	i65	0,12	i65	400	i65	710	i65	710
i66	0,15	i66	0,11	i66	210	i66	689	i66	689
i67	0,13	i67	0,09	i67	225	i67	319	i67	319
i68	0,09	i68	0,10	i68	195	i68	329	i68	329
i69	0,16	i69	0,11	i69	135	i69	325	i69	325
i70	0,16	i70	0,08	i70	260	i70	720	i70	720
i71	0,06	i71	0,10	i71	260	i71	780	i71	780
i72	0,1	i72	0,09	i72	100	i72	750	i72	750
i73	0,18	i73	0,13	i73	170	i73	789	i73	789
i74	0,17	i74	0,09	i74	310	i74	560	i74	560
i75	0,18	i75	0,08	i75	285	i75	639	i75	639
i76	0,17	i76	0,13	i76	310	i76	575	i76	575
i77	0,21	i77	0,10	i77	285	i77	649	i77	649
i78	0,07	i78	0,12	i78	32	i78	619	i78	619
i79	0,13	i79	0,12	i79	110	i79	659	i79	659
i80	0,2	i80	0,11	i80	215	i80	639	i80	639
i81	0,04	i81	0,11	i81	340	i81	1450	i81	1450
i82	0,23	i82	0,15	i82	70	i82	1349	i82	1349
i83	0,14	i83	0,10	i83	390	i83	1475	i83	1475
i84	0,09	i84	0,11	i84	235	i84	1329	i84	1329
i85	0,2	i85	0,11	i85	150	i85	3450	i85	3450
i86	0,03	i86	0,13	i86	340	i86	1265	i86	1265
i87	0,03	i87	0,09	i87	50	i87	1925	i87	1925
i88	0,21	i88	0,12	i88	50	i88	749	i88	749

i89	0,2	i89	0,14	i89	260	i89	1150	i89	1150
i90	0,19	i90	0,09	i90	240	i90	765	i90	765
i91	0,14	i91	0,11	i91	315	i91	985	i91	985
i92	0,06	i92	0,12	i92	190	i92	945	i92	945

A thorough forecasting framework was created as an extra analytical tool to help Azure Bosphorus Restaurant's operational performance. The Simple Naive Model, Naive Model with Linear Trend, Naive Model with Exponential Trend, Seasonal Naive Model, and Seasonal Naive Model with Linear Trend were among the time series forecasting methods used in this framework. Every technique was methodically applied to the historical demand data that was available, which was divided into three meal periods: breakfast, lunch, and supper. Finding the best forecasting model for each time period was the goal in order to more precisely predict client demand. By improving demand planning, cutting down on overproduction, and avoiding waste, this forecasting project helps make restaurant operations more economical and sustainable

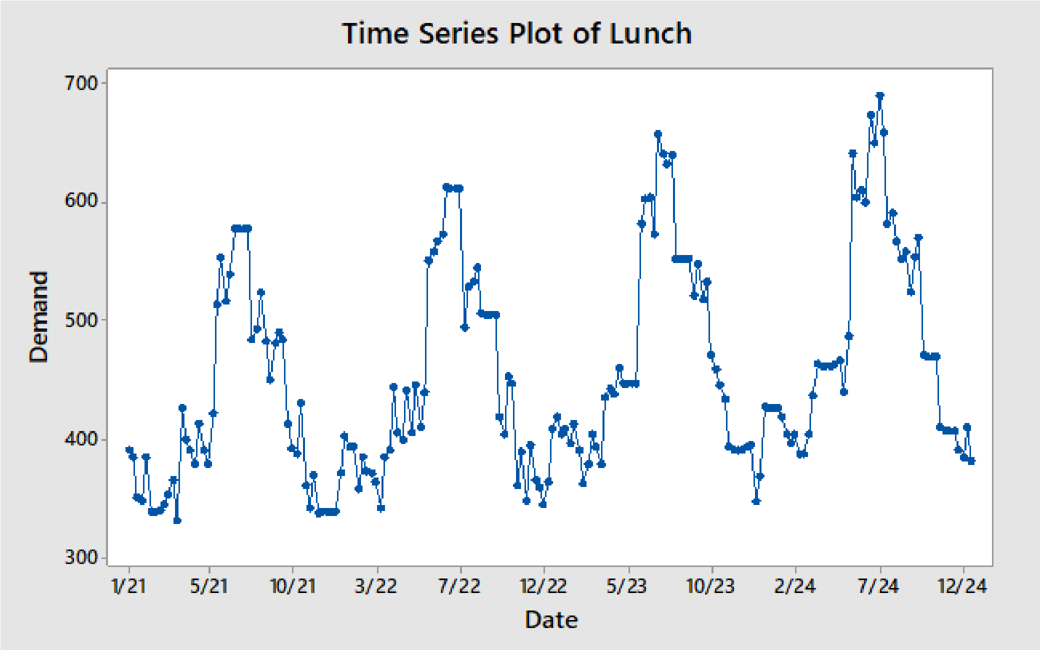
Breakfast

Forecast Error Measures	Mean	ME	MAE	MAPE	RMSE
Simple Naive Model	323,61	0,137	28,9	9,03%	39,202
Naive Model with Linear Trend	323,87	0,177	50,5	15,40%	62,747
Naive Model with Exponential Trend	328,57	-4,52	50,85	15,60%	64,632
Seasonal Naive Model	320,17	10,929	19,05	5,86%	22,913
Seasonal Naive Model with Linear Trend	331,48	0,253	24,9	7,99%	31,71



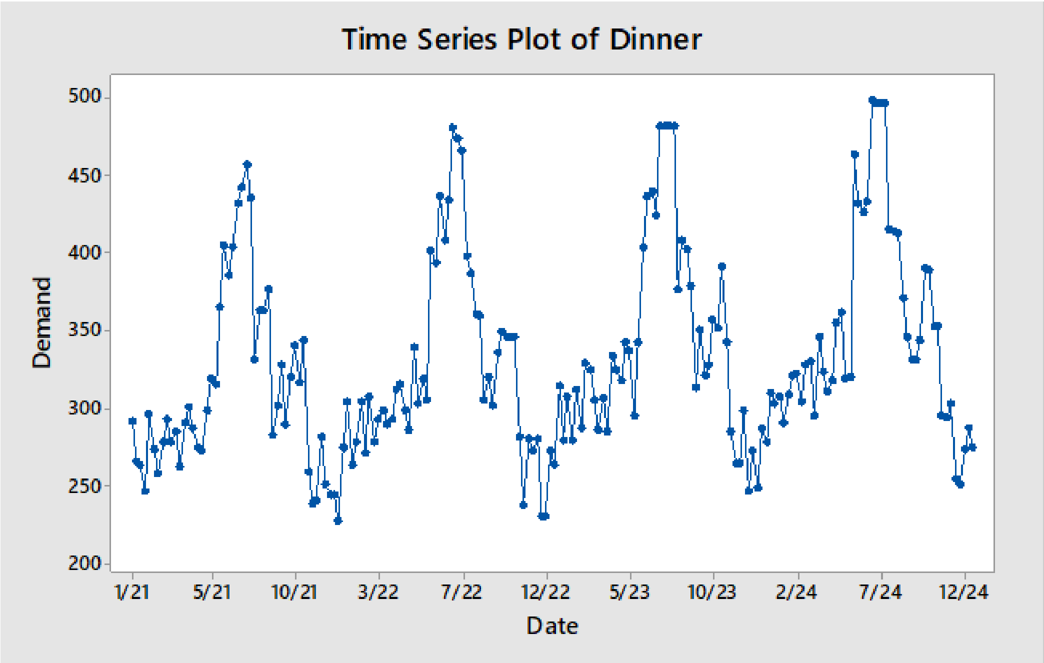
Lunch

Forecast Error Measures	Mean	ME	MAE	MAPE	RMSE
Simple Naive Model	447,08	1,092	25,63	5,81%	37,082
Naive Model with Linear Trend	448,5	0,169	43,17	9,80%	55,872
Naive Model with Exponential Trend	451,57	-2,904	43,54	9,80%	56,933
Seasonal Naive Model	439,19	24,333	27,07	5,92%	31,914
Seasonal Naive Model with Linear Trend	464,06	0,578	25,3	5,80%	31,98



Dinner

Forecast Error Measures	Mean	ME	MAE	MAPE	RMSE
Simple Naive Model	327,77	0,275	25,82	8,11%	33,64
Naive Model with Linear Trend	328,27	0,254	42,73	13,50%	52,533
Naive Model with Exponential Trend	331,68	-3,153	42,62	13,40%	52,103
Seasonal Naive Model	322,8	14,643	20,9	6,25%	26,185
Seasonal Naive Model with Linear Trend	338,08	0,108	30,18	9,22%	35,741



Chapter 5 Analysis of Results

5.1 Implementation and Continuous Feedback

A thorough food waste reduction approach that was iterative, adaptable, and motivated by active stakeholder participation was put into place at the Azure Bosphorus Restaurant. The model was created to improve preparation and service quantities with the ultimate goal of minimizing food waste while preserving operational efficiency. It was designed and verified using historical data. This model was run using an optimization framework created with the General Algebraic Modeling System (GAMS), which offered the best way to figure out how best to distribute resources among different decision variables, such as staff scheduling, ingredient inventories, and portion sizes. Following validation, as part of an initial phased deployment approach, the model's optimized amounts were included into the restaurant's everyday operations. Breakfast service was chosen for the initial phase of deployment due to its more stable demand and lower operational risk, which will help adoption go more smoothly. This made it possible to test the model's results in a controlled setting and see early advancements. Lunch and dinner services were added to the testing phase since the model showed encouraging results, including a noticeable decrease in overproduction and food waste. These services provided a more dynamic testing environment for model performance in real-world scenarios because of their greater degree of consumer demand variability and menu complexity. The creation of a real-time feedback loop was a crucial step in the implementation process because it allowed for constant improvement and modification. Disparities between the model's predictions and actual results were methodically recorded, with restaurant employees ,including chefs, kitchen managers, and front-line staff, noting variations brought on by unforeseen events like last-minute reservations, ingredient shortages, or unexpected spikes in demand. Weekly summaries of this qualitative data were loaded into a feedback dashboard, which enabled the project team to analyze the accuracy of demand estimates, spot possible inefficiencies, and gauge how realistic operational restrictions were.Prior to and following implementation, quantitative performance metrics were also monitored, such as waste volume (divided into ingredient, plate, and unmet food waste), cost variance in relation to budgeted food expenses, and customer satisfaction ratings. These metrics were used as a standard by which to measure the model's effectiveness. The findings showed a statistically significant decrease in waste-related expenses and better adherence to preparation plans, which resulted in waste reduction and more effective inventory management. Additionally, client satisfaction stayed consistent, suggesting that service quality was unaffected by the model's deployment. Simultaneously, the management team of the restaurant held training sessions for the planning and culinary staff to provide them the skills they needed to understand the model's results and react to the best suggestions. These meetings also provided a great chance to record operational insights that were previously missing from the dataset, like changes in staff workload and real-time limitations on kitchen storage capacities. The model changed to represent the dynamic nature of the restaurant's operations through iterative recalibration and ongoing feedback. For example, the model's forecast coefficients were revised to take into consideration recent variations in demand, and ingredient waste factors were modified for new menu items. Thus, the feedback system made it possible to dynamically adjust the model's parameters, improving its forecast accuracy and lowering food waste even further. In addition to improving operational performance, this approach of ongoing learning promoted a data-driven decision-making culture within the restaurant's management system, which is consistent with more general sustainability objectives.

5.2 Sensitivity Analysis

---- 108 VARIABLE Q.L Quantity prepared

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	39.600	40.800	44.400	43.200	44.400	48.000	50.400	54.000	55.200	55.200	45.600	38.400
i2	16.800	15.600	18.000	18.000	15.600	15.600	26.400	22.800	21.600	22.800	19.200	16.800
i3	37.200	40.800	43.200	39.600	43.200	44.400	55.200	49.200	48.000	49.200	44.400	34.800
i4	32.400	36.000	34.800	34.800	32.400	31.200	38.400	43.200	45.600	45.600	36.000	31.200
i5	16.800	16.800	16.800	18.000	19.200	16.800	27.600	22.800	26.400	27.600	15.600	16.800
i6	31.200	31.200	28.800	33.600	37.200	40.800	43.200	42.000	45.600	45.600	30.000	30.000
i7	27.600	28.800	31.200	30.000	33.600	32.400	40.800	37.200	37.200	39.600	26.400	26.400
i8	32.400	36.000	38.400	34.800	34.800	37.200	43.200	43.200	40.800	43.200	37.200	31.200
i9	46.800	45.600	49.200	50.400	50.400	49.200	55.200	62.400	62.400	64.800	50.400	44.400
i10	32.400	33.600	31.200	34.800	36.000	33.600	36.000	43.200	40.800	42.000	26.400	31.200
i11	8.880	8.880	5.700	10.260	16.800	15.000	9.720	11.400	6.960	2.220	2.940	7.980
i12	44.400	45.600	49.200	48.000	52.800	56.400	56.400	60.000	62.400	60.000	49.200	42.000
i13	24.000	27.600	30.000	25.200	28.800	31.200	39.600	31.200	28.800	30.000	27.600	22.800
i14	21.600	24.000	27.600	22.800	24.000	24.000	30.000	28.800	30.000	30.000	26.400	20.400
i15	54.000	57.600	61.200	58.800	62.400	66.000	75.600	73.200	70.800	73.200	60.000	51.600
i16	44.400	48.000	48.000	48.000	50.400	52.800	56.400	60.000	62.400	61.200	46.800	42.000
i17	33.600	32.400	34.800	36.000	40.800	43.200	54.000	44.400	42.000	44.400	32.400	32.400
i18	36.000	34.800	38.400	38.400	36.000	39.600	42.000	48.000	49.200	48.000	39.600	33.600
i19	37.200	38.400	42.000	40.800	40.800	38.400	39.600	50.400	48.000	50.400	37.200	36.000
i20	51.600	52.800	54.000	56.400	61.200	64.800	74.400	69.600	69.600	69.600	51.600	49.200
i22	36.000	38.400	36.000	38.400	40.800	39.600	42.000	48.000	48.000	45.600	37.200	33.600
i23	49.200	52.800	56.400	54.000	51.600	52.800	57.600	67.200	67.200	68.400	57.600	48.000
i24	43.200	46.800	44.400	46.800	49.200	48.000	51.600	57.600	61.200	58.800	43.200	40.800
i25	49.200	48.000	46.800	52.800	56.400	58.800	61.200	66.000	69.600	69.600	44.400	46.800
i26	18.000	20.400	24.000	19.200	19.200	18.000	21.600	24.000	21.600	24.000	20.400	16.800
i27	26.400	26.400	28.800	28.800	31.200	31.200	42.000	36.000	37.200	39.600	27.600	25.200
i28	28.800	30.000	31.200	31.200	28.800	31.200	31.200	38.400	42.000	42.000	27.600	27.600
i30	54.000	52.800	51.600	58.800	58.800	56.400	55.200	73.200	76.800	74.400	49.200	51.600
i32	22.800	20.400	20.400	24.000	27.600	25.200	26.400	30.000	32.400	32.400	15.600	21.600
i33	26.400	30.000	33.600	28.800	27.600	30.000	37.200	36.000	38.400	36.000	34.800	25.200
i34	25.200	26.400	26.400	27.600	31.200	32.400	33.600	34.800	37.200	39.600	25.200	25.200
i35	22.800	22.800	21.600	24.000	25.200	27.600	38.400	30.000	32.400	32.400	19.200	21.600
i36	32.400	33.600	31.200	34.800	33.600	33.600	32.400	43.200	44.400	45.600	27.600	31.200
i39	27.600	27.600	26.400	30.000	33.600	37.200	39.600	37.200	34.800	33.600	21.600	26.400
i40	36.000	34.800	32.400	38.400	40.800	44.400	45.600	48.000	46.800	49.200	28.800	33.600
i41	43.200	44.400	43.200	46.800	45.600	45.600	56.400	57.600	57.600	56.400	38.400	40.800
i42	33.600	32.400	33.600	36.000	40.800	43.200	44.400	44.400	44.400	46.800	31.200	32.400
i43	25.200	26.400	26.400	27.600	25.200	22.800	27.600	34.800	36.000	36.000	27.600	25.200

---- 108 VARIABLE S.L Quantity served

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	33.000	34.000	37.000	36.000	37.000	40.000	42.000	45.000	46.000	46.000	38.000	32.000
i2	14.000	13.000	15.000	15.000	13.000	13.000	22.000	19.000	18.000	19.000	16.000	14.000
i3	31.000	34.000	36.000	33.000	36.000	37.000	46.000	41.000	40.000	41.000	37.000	29.000
i4	27.000	30.000	29.000	29.000	27.000	26.000	32.000	36.000	38.000	38.000	30.000	26.000
i5	14.000	14.000	14.000	15.000	16.000	14.000	23.000	19.000	22.000	23.000	13.000	14.000
i6	26.000	26.000	24.000	28.000	31.000	34.000	36.000	35.000	38.000	38.000	25.000	25.000
i7	23.000	24.000	26.000	25.000	28.000	27.000	34.000	31.000	31.000	33.000	22.000	22.000
i8	27.000	30.000	32.000	29.000	29.000	31.000	36.000	36.000	34.000	36.000	31.000	26.000
i9	39.000	38.000	41.000	42.000	42.000	41.000	46.000	52.000	52.000	54.000	42.000	37.000
i10	27.000	28.000	26.000	29.000	30.000	28.000	30.000	36.000	34.000	35.000	22.000	26.000
i11	7.400	7.400	4.750	8.550	14.000	12.500	8.100	9.500	5.800	1.850	2.450	6.650
i12	37.000	38.000	41.000	40.000	44.000	47.000	47.000	50.000	52.000	50.000	41.000	35.000
i13	20.000	23.000	25.000	21.000	24.000	26.000	33.000	26.000	24.000	25.000	23.000	19.000
i14	18.000	20.000	23.000	19.000	20.000	20.000	25.000	24.000	25.000	25.000	22.000	17.000
i15	45.000	48.000	51.000	49.000	52.000	55.000	63.000	61.000	59.000	61.000	50.000	43.000
i16	37.000	40.000	40.000	40.000	42.000	44.000	47.000	50.000	52.000	51.000	39.000	35.000
i17	28.000	27.000	29.000	30.000	34.000	36.000	45.000	37.000	35.000	37.000	27.000	27.000
i18	30.000	29.000	32.000	32.000	30.000	33.000	35.000	40.000	41.000	40.000	33.000	28.000
i19	31.000	32.000	35.000	34.000	34.000	32.000	33.000	42.000	40.000	42.000	31.000	30.000
i20	43.000	44.000	45.000	47.000	51.000	54.000	62.000	58.000	58.000	58.000	43.000	41.000
i22	30.000	32.000	30.000	32.000	34.000	33.000	35.000	40.000	40.000	38.000	31.000	28.000
i23	41.000	44.000	47.000	45.000	43.000	44.000	48.000	56.000	56.000	57.000	48.000	40.000
i24	36.000	39.000	37.000	39.000	41.000	40.000	43.000	48.000	51.000	49.000	36.000	34.000
i25	41.000	40.000	39.000	44.000	47.000	49.000	51.000	55.000	58.000	58.000	37.000	39.000
i26	15.000	17.000	20.000	16.000	16.000	15.000	18.000	20.000	18.000	20.000	17.000	14.000
i27	22.000	22.000	24.000	24.000	26.000	26.000	35.000	30.000	31.000	33.000	23.000	21.000
i28	24.000	25.000	26.000	26.000	24.000	26.000	26.000	32.000	35.000	35.000	23.000	23.000
i30	45.000	44.000	43.000	49.000	49.000	47.000	46.000	61.000	64.000	62.000	41.000	43.000
i32	19.000	17.000	17.000	20.000	23.000	21.000	22.000	25.000	27.000	27.000	13.000	18.000
i33	22.000	25.000	28.000	24.000	23.000	25.000	31.000	30.000	32.000	30.000	29.000	21.000
i34	21.000	22.000	22.000	23.000	26.000	27.000	28.000	29.000	31.000	33.000	21.000	21.000
i35	19.000	19.000	18.000	20.000	21.000	23.000	32.000	25.000	27.000	27.000	16.000	18.000
i36	27.000	28.000	26.000	29.000	28.000	28.000	27.000	36.000	37.000	38.000	23.000	26.000
i39	23.000	23.000	22.000	25.000	28.000	31.000	33.000	31.000	29.000	28.000	18.000	22.000
i40	30.000	29.000	27.000	32.000	34.000	37.000	38.000	40.000	39.000	41.000	24.000	28.000
i41	36.000	37.000	36.000	39.000	38.000	38.000	47.000	48.000	48.000	47.000	32.000	34.000
i42	28.000	27.000	28.000	30.000	34.000	36.000	37.000	37.000	37.000	39.000	26.000	27.000
i43	21.000	22.000	22.000	23.000	21.000	19.000	23.000	29.000	30.000	30.000	23.000	21.000

---- 108 VARIABLE Z.L = 2539688.977 Total waste cost

Following the removal of the dishes with the highest food waste, The monthly preparation (Q(i,t)) and service (S(i,t)) amounts for each over a 12-month period are crucially revealed by the output of the GAMS optimization model. These figures reflect the best choices made to reduce the overall cost of food waste, which is 2,539,688.98 TL according to the objective function. While the served numbers are also utilized to determine plate waste, the difference between the amounts prepared and those served directly represents unmet food waste. Additionally, the model includes dish-specific metrics like cost coefficients and ingredient waste factors, which makes the solution extremely flexible to Azure Bosphorus Restaurant's operational reality. The outcomes show how to successfully balance competing goals: reducing waste and overproduction while maintaining sufficient customer service standards and staying within kitchen capacity limitations. By offering a quantitative basis for production planning that harmonizes financial objectives with sustainable practices, this output aids in the restaurant's decision-making. Through real-time input and ongoing recalibration, the model's integration into a larger Decision Support System, as described in the project, guarantees adaptability and promotes a data-driven culture of operational efficiency and waste reduction.

And here after we changed the capacity and also the rate from 4 to 3.5 with increasing beta from 0.85 to 0.90.

---- 108 VARIABLE Q.L Quantity prepared

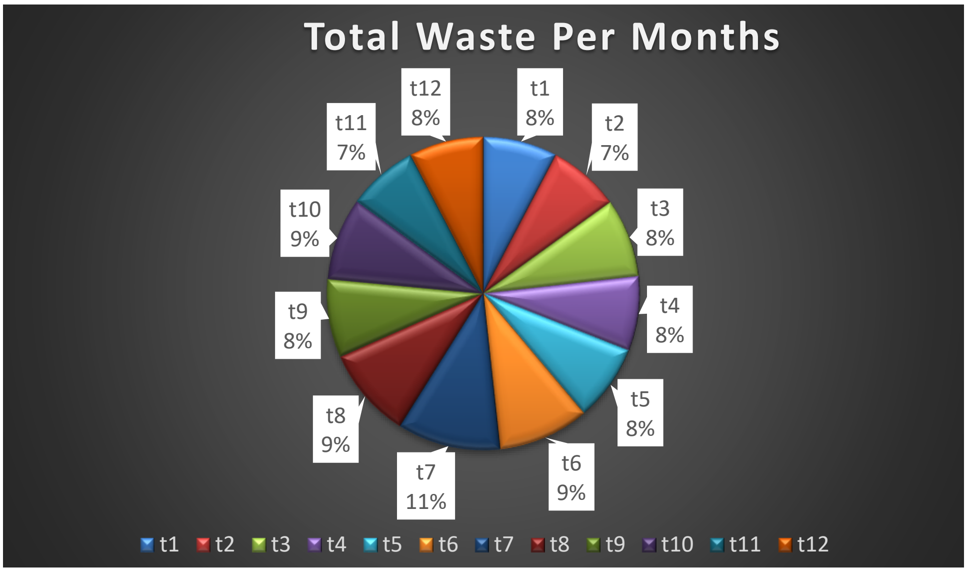
	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	37.950	39.100	42.550	41.400	42.550	46.000	48.300	51.750	52.900	52.900	43.700	36.800
i2	16.100	14.950	17.250	17.250	14.950	14.950	25.300	21.850	20.700	21.850	18.400	16.100
i3	35.650	39.100	41.400	37.950	41.400	42.550	52.900	47.150	46.000	47.150	42.550	33.350
i4	31.050	34.500	33.350	33.350	31.050	29.900	36.800	41.400	43.700	43.700	34.500	29.900
i5	16.100	16.100	16.100	17.250	18.400	16.100	26.450	21.850	25.300	26.450	14.950	16.100
i6	29.900	29.900	27.600	32.200	35.650	39.100	41.400	40.250	43.700	43.700	28.750	28.750
i7	26.450	27.600	29.900	28.750	32.200	31.050	39.100	35.650	35.650	37.950	25.300	25.300
i8	31.050	34.500	36.800	33.350	33.350	35.650	41.400	41.400	39.100	41.400	35.650	29.900
i9	44.850	43.700	47.150	48.300	48.300	47.150	52.900	59.800	59.800	62.100	48.300	42.550
i10	31.050	32.200	29.900	33.350	34.500	32.200	34.500	41.400	39.100	40.250	25.300	29.900
i11	30.590	34.040	29.325	33.005	44.850	41.400	36.110	40.250	39.330	36.685	22.195	28.865
i12	42.550	43.700	47.150	46.000	50.600	54.050	54.050	57.500	59.800	57.500	47.150	40.250
i13	23.000	26.450	28.750	24.150	27.600	29.900	37.950	29.900	27.600	28.750	26.450	21.850
i14	20.700	23.000	26.450	21.850	23.000	23.000	28.750	27.600	28.750	28.750	25.300	19.550
i15	51.750	55.200	58.650	56.350	59.800	63.250	72.450	70.150	67.850	70.150	57.500	49.450
i16	42.550	46.000	46.000	46.000	48.300	50.600	54.050	57.500	59.800	58.650	44.850	40.250
i17	32.200	31.050	33.350	34.500	39.100	41.400	51.750	42.550	40.250	42.550	31.050	31.050
i18	34.500	33.350	36.800	36.800	34.500	37.950	40.250	46.000	47.150	46.000	37.950	32.200
i19	35.650	36.800	40.250	39.100	39.100	36.800	37.950	48.300	46.000	48.300	35.650	34.500
i20	49.450	50.600	51.750	54.050	58.650	62.100	71.300	66.700	66.700	66.700	49.450	47.150
i22	34.500	36.800	34.500	36.800	39.100	37.950	40.250	46.000	46.000	43.700	35.650	32.200
i23	47.150	50.600	54.050	51.750	49.450	50.600	55.200	64.400	64.400	65.550	55.200	46.000
i24	41.400	44.850	42.550	44.850	47.150	46.000	49.450	55.200	58.650	56.350	41.400	39.100
i25	47.150	46.000	44.850	50.600	54.050	56.350	58.650	63.250	66.700	66.700	42.550	44.850
i26	17.250	19.550	23.000	18.400	18.400	17.250	20.700	23.000	20.700	23.000	19.550	16.100
i27	25.300	25.300	27.600	27.600	29.900	29.900	40.250	34.500	35.650	37.950	26.450	24.150
i28	27.600	28.750	29.900	29.900	27.600	29.900	29.900	36.800	40.250	40.250	26.450	26.450
i30	51.750	50.600	49.450	56.350	56.350	54.050	52.900	70.150	73.600	71.300	47.150	49.450
i32	21.850	19.550	19.550	23.000	26.450	24.150	25.300	28.750	31.050	31.050	14.950	20.700
i33	25.300	28.750	32.200	27.600	26.450	28.750	35.650	34.500	36.800	34.500	33.350	24.150
i34	24.150	25.300	25.300	26.450	29.900	31.050	32.200	33.350	35.650	37.950	24.150	24.150
i35	21.850	21.850	20.700	23.000	24.150	26.450	36.800	28.750	31.050	31.050	18.400	20.700
i36	31.050	32.200	29.900	33.350	32.200	32.200	31.050	41.400	42.550	43.700	26.450	29.900
i37	49.450	48.300	51.750	54.050	51.750	55.200	65.550	66.700	64.400	63.250	52.900	47.150
i39	26.450	26.450	25.300	28.750	32.200	35.650	37.950	35.650	33.350	32.200	20.700	25.300
i40	34.500	33.350	31.050	36.800	39.100	42.550	43.700	46.000	44.850	47.150	27.600	32.200
i41	41.400	42.550	41.400	44.850	43.700	43.700	54.050	55.200	55.200	54.050	36.800	39.100
i42	32.200	31.050	32.200	34.500	39.100	41.400	42.550	42.550	42.550	44.850	29.900	31.050
i43	24.150	25.300	25.300	26.450	24.150	21.850	26.450	33.350	34.500	34.500	26.450	24.150

---- 108 VARIABLE S.L Quantity served

	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
i1	33.000	34.000	37.000	36.000	37.000	40.000	42.000	45.000	46.000	46.000	38.000	32.000
i2	14.000	13.000	15.000	15.000	13.000	13.000	22.000	19.000	18.000	19.000	16.000	14.000
i3	31.000	34.000	36.000	33.000	36.000	37.000	46.000	41.000	40.000	41.000	37.000	29.000
i4	27.000	30.000	29.000	29.000	27.000	26.000	32.000	36.000	38.000	38.000	30.000	26.000
i5	14.000	14.000	14.000	15.000	16.000	14.000	23.000	19.000	22.000	23.000	13.000	14.000
i6	26.000	26.000	24.000	28.000	31.000	34.000	36.000	35.000	38.000	38.000	25.000	25.000
i7	23.000	24.000	26.000	25.000	28.000	27.000	34.000	31.000	31.000	33.000	22.000	22.000
i8	27.000	30.000	32.000	29.000	29.000	31.000	36.000	36.000	34.000	36.000	31.000	26.000
i9	39.000	38.000	41.000	42.000	42.000	41.000	46.000	52.000	52.000	54.000	42.000	37.000
i10	27.000	28.000	26.000	29.000	30.000	28.000	30.000	36.000	34.000	35.000	22.000	26.000
i11	26.600	29.600	25.500	28.700	39.000	36.000	31.400	35.000	34.200	31.900	19.300	25.100
i12	37.000	38.000	41.000	40.000	44.000	47.000	47.000	50.000	52.000	50.000	41.000	35.000
i13	20.000	23.000	25.000	21.000	24.000	26.000	33.000	26.000	24.000	25.000	23.000	19.000
i14	18.000	20.000	23.000	19.000	20.000	20.000	25.000	24.000	25.000	25.000	22.000	17.000
i15	45.000	48.000	51.000	49.000	52.000	55.000	63.000	61.000	59.000	61.000	50.000	43.000
i16	37.000	40.000	40.000	40.000	42.000	44.000	47.000	50.000	52.000	51.000	39.000	35.000
i17	28.000	27.000	29.000	30.000	34.000	36.000	45.000	37.000	35.000	37.000	27.000	27.000
i18	30.000	29.000	32.000	32.000	30.000	33.000	35.000	40.000	41.000	40.000	33.000	28.000
i19	31.000	32.000	35.000	34.000	34.000	32.000	33.000	42.000	40.000	42.000	31.000	30.000
i20	43.000	44.000	45.000	47.000	51.000	54.000	62.000	58.000	58.000	58.000	43.000	41.000
i22	30.000	32.000	30.000	32.000	34.000	33.000	35.000	40.000	40.000	38.000	31.000	28.000
i23	41.000	44.000	47.000	45.000	43.000	44.000	48.000	56.000	56.000	57.000	48.000	40.000
i24	36.000	39.000	37.000	39.000	41.000	40.000	43.000	48.000	51.000	49.000	36.000	34.000
i25	41.000	40.000	39.000	44.000	47.000	49.000	51.000	55.000	58.000	58.000	37.000	39.000
i26	15.000	17.000	20.000	16.000	16.000	15.000	18.000	20.000	18.000	20.000	17.000	14.000
i27	22.000	22.000	24.000	24.000	26.000	26.000	35.000	30.000	31.000	33.000	23.000	21.000
i28	24.000	25.000	26.000	26.000	24.000	26.000	26.000	32.000	35.000	35.000	23.000	23.000
i30	45.000	44.000	43.000	49.000	49.000	47.000	46.000	61.000	64.000	62.000	41.000	43.000
i32	19.000	17.000	17.000	20.000	23.000	21.000	22.000	25.000	27.000	27.000	13.000	18.000
i33	22.000	25.000	28.000	24.000	23.000	25.000	31.000	30.000	32.000	30.000	29.000	21.000
i34	21.000	22.000	22.000	23.000	26.000	27.000	28.000	29.000	31.000	33.000	21.000	21.000
i35	19.000	19.000	18.000	20.000	21.000	23.000	32.000	25.000	27.000	27.000	16.000	18.000
i36	27.000	28.000	26.000	29.000	28.000	28.000	27.000	36.000	37.000	38.000	23.000	26.000
i37	43.000	42.000	45.000	47.000	45.000	48.000	57.000	58.000	56.000	55.000	46.000	41.000
i39	23.000	23.000	22.000	25.000	28.000	31.000	33.000	31.000	29.000	28.000	18.000	22.000
i40	30.000	29.000	27.000	32.000	34.000	37.000	38.000	40.000	39.000	41.000	24.000	28.000
i41	36.000	37.000	36.000	39.000	38.000	38.000	47.000	48.000	48.000	47.000	32.000	34.000
i42	28.000	27.000	28.000	30.000	34.000	36.000	37.000	37.000	37.000	39.000	26.000	27.000
i43	21.000	22.000	22.000	23.000	21.000	19.000	23.000	29.000	30.000	30.000	23.000	21.000

---- 108 VARIABLE Z.L = 2367007.544 Total waste cost

The GAMS optimization model produced an updated solution that reflects a more conservative yet effective production strategy after the kitchen capacity constraints were changed, the preparation-to-service ratio was changed from 4 to 3.5, and the β parameter was raised from 0.85 to 0.90. The improved output yields a total food waste cost of 2,367,007.54 TL, which is a major improvement over the previous iteration. It contains optimized monthly preparation (Q(i,t)) and service amounts (S(i,t)) across a 12-month planning horizon. The behaviour of the model was directly affected by these modifications. A leaner approach to production was spurred by the lower preparation ratio, which limited excessive overpreparation and minimized food waste that went unused. Concurrently, by guaranteeing that prepared quantities continue to be responsive to actual consumption patterns, the rise in βthe area which represents stricter lower-bound coverage for predicted demand helped sustain high levels of customer satisfaction. The model was forced to use kitchen resources and time more effectively because of the stricter capacity limitations, which also introduced realistic operational boundaries. The optimization process retained dish-specific waste coefficients and cost parameters, which allowed the model to precisely reflect the effects of ingredients and plate waste. This ensured that sustainability and economic performance were in line by constantly balancing the trade-off between waste reduction and service quality. The model's usefulness as a component of the Azure Bosphorus Restaurant's Decision Support System is further supported by this revised setup. The system maintains its robustness under a variety of operational conditions thanks to real-time recalibration made possible by parameter sensitivity (β and preparation ratios). Finally, this data-driven optimization approach supports long term food waste reduction initiatives that align with both financial and environmental objectives, improves resource usage, and encourages well-informed decision-making.



5.3 Limitations

The created optimization model and its forecasting framework have a number of limitations that should be discussed, notwithstanding their effective application and encouraging outcomes. Data limits, model assumptions, operational constraints, and external dependencies are the four primary categories into which these limitations fall.

Data Limitations:

The quality and granularity of the input data have a significant impact on the accuracy and resilience of any optimization model. The project team had access to cost reports, kitchen logs, and demand data from the past, but some of these datasets were incomplete or lacked real-time resolution. For example, there was inconsistent documentation of real-time tracking of individual portion sizes and ingredient usage, which could have resulted in an underestimation or overestimation of waste elements. Similarly, due to a lack of data, subjective elements such as staff cooking practices, customer taste preferences, or the impact of promotional events could not be statistically included.

Simplifying Model Assumptions:

A number of simplifying assumptions were made in order to guarantee the tractability and solvability of the model. The model might not adequately represent the inherent diversity of restaurant environments since it makes the assumptions of deterministic demand projections and linear cost correlations. For instance, the model excludes stochastic components that could drastically change preparation requirements, such as unforeseen weather, supplier delays, or surges in walk-in customers. Furthermore, fixed values for waste factors might not account for contextual or seasonal changes in worker behavior or kitchen operations.

Operational and Cultural Constraints:

Due to long-standing operating procedures, there was some opposition to the practical use of even the most technically sound model. Employees occasionally favored heuristic decision-making over data-driven advice, especially those with years of culinary experience. In several instances, customer modification requests or time constraints during busy hours made it difficult to follow the model's recommendations. Additionally, the model makes the assumption that preparation quantities are followed exactly, but in practice, small variations are frequent since kitchen activity moves quickly.

External and Strategic Factors:

Lastly, variables beyond the restaurant's direct control have an impact on the model's functionality and reach. Demand dynamics can be considerably changed by strategic choices like menu modifications, supplier partnerships, or hotel-level promotions. Furthermore, the model's assumptions and parameter values may be rendered invalid by unanticipated macro-level interruptions like supply chain failures, pandemic-related constraints, or economic downturns.

Chapter 6 Conclusions and Discussions

6.1 Design of DSS

The Decision Support System (DSS) created for this project is an integrative platform intended to direct Azure Bosphorus Restaurant's food preparation planning in order to reduce food waste and related expenses while upholding excellent service standards. A time-series forecasting module and a mathematical optimization model integrated into GAMS are its two main constituents. A comprehensive, data-driven system that improves managerial decision-making in the face of operational restrictions and uncertainty is created when these technologies are combined. System Architecture and Components

The DSS is structured around a modular architecture comprising the following integrated subsystems:

1. Demand Forecasting Module:

To forecast client demand, this component uses past monthly data that has been divided into breakfast, lunch, and supper times. Metrics including Mean Absolute Error (MAE), Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE) were used to evaluate and validate several time series models, including the Seasonal Naive Model with Linear Trend and other variations. To produce dish-level demand estimates, the model with the highest accuracy for each lunch period was chosen. The optimization model uses these projections as input parameters.

2. Mathematical Optimization Module (GAMS):

A linear programming model created in GAMS forms the basis of the DSS. By taking into consideration unmet food waste, ingredient waste, and plate waste, the model's target function aims to minimize the overall cost of food waste. The model makes use of real-world operating characteristics such capacity restrictions, cost coefficients, and waste rates unique to each dish. The amounts of each item to be made (Q) and served (S) during mealtimes are the main deciding factors. To guarantee viability, several operational restrictions are incorporated, such as kitchen capacity, demand thresholds, perishability limits, and proxies for customer satisfaction.

3. Feedback and Adaptation Mechanism:

The DSS has an integrated feedback system to stay relevant in a changing operational environment. Weekly reports on overproduction incidents, service irregularities, and differences between predicted and actual demand are recorded and examined. Adaptive learning and ongoing system development are made possible by these insights, which guide the periodic recalibration of model parameters, such as updating waste coefficients or improving forecasting models.

4. User Interface and Managerial Dashboard:

The DSS outputs are intended to be managerially interpretable even though they are not implemented as software GUI. Demand projections and GAMS outputs are combined to provide a structured decision report that offers weekly and daily preparation instructions. To help with production planning, chefs and kitchen managers are informed of this information. To enable quick managerial evaluation, key metrics like anticipated waste volume, cost savings, and departure from actual demand are displayed in a dashboard style.

Integration and Operational Flow

The DSS operates in a cyclical flow:

1.Input Phase: The system is updated with waste parameters, kitchen limits, and historical sales data.

2. Forecasting Phase: Demand for each meal period is predicted by time series models.

3.Optimization Phase: To produce the ideal preparation amounts, GAMS is fed with forecasts and operating characteristics.

4.Implementation Phase: The actual food preparation process incorporates the recommended quantities.

5.Monitoring Phase: To update the system, real-time feedback and deviations are gathered, examined, and utilized. The DSS is kept practically applicable and contextually accurate by this closed-loop procedure.

Advantages from a Strategic Perspective

The created DSS considers both long-term strategic objectives and immediate operational efficiency:

Operational Efficiency: The restaurant lowers the risk of resource overuse and improves cost control by avoiding waste and matching production quantities with statistically predicted demand.

Sustainability Compliance: By lowering the carbon and waste footprint of food service operations, the system helps achieve UN Sustainable Development Goal 12 (Responsible Consumption and Production).

Scalability and Replicability: The DSS's modular architecture enables scalability among various eateries as well as possible connectivity with online platforms like ERP and POS (Point-of-Sale) systems for real-time automation.

6.2 Economical, Social, Ethical and Environmental Impacts

The proposed food waste minimization model developed for Azure Bosphorus Restaurant carries multifaceted impacts that extend far beyond mere cost savings. By integrating operations research with sustainability principles, the project demonstrates significant potential to contribute to economic resilience, social responsibility, ethical practices, and environmental stewardship within the hospitality sector.

Economic Impact

The project's primary goal is to lessen the financial strain caused by wasteful and inefficient food production. The technique directly targets overproduction, one of the most financially damaging inefficiencies in hotel restaurants, by optimizing the quantity of meals prepared using predictive analytics and cost-sensitive linear programming. More accurate demand forecasting and waste cost reduction are better ways to manage ingredient costs, which usually make up a significant amount of variable expenses. By increasing the ratio of food given to food purchased, this model's application is anticipated to decrease needless procurement, prevent food deterioration, and boost profitability.

Additionally, better forecasting accuracy aids in resource allocation, allowing the restaurant to run with lower buffer stocks and inventory levels. This reduces holding costs and makes it possible for the supply chain to react more quickly. From the standpoint of the industry as a whole, widespread use of these models may result in improved financial performance for hospitality businesses, particularly in the face of supply volatility and inflationary pressures.

Social Impact

The project's societal ramifications are especially pertinent when considering fair resource distribution and food security. Every day, hotels throw out large amounts of edible food, but millions of people around the world go hungry. By reducing waste, the restaurant can donate extra food to nearby charity or food banks when it is safe to do so. The model provides the groundwork for acceptable redistribution schemes, even though they are outside the current practical scope.

Furthermore, by encouraging data literacy and digital transformation among employees, the project supports the restaurant's internal social structure. Model implementation-related training initiatives promote a culture of ongoing education, worker empowerment, and collaborative decision-making. These intangible advantages raise employee satisfaction, lessen opposition to technology adoption, and help the workers support the restaurant's larger sustainability goal.

Ethical Impact

In terms of ethics, the project encourages responsible consumption and accountability, two of the Sustainable Development Goals (SDG 12: Responsible Consumption and Production) of the UN. In a society when social inequity and resource scarcity are on the rise, reducing food waste is not only a practical problem but also a moral requirement. This model helps management make transparent, evidence-based decisions that align with ethical standards of stewardship and fairness. Furthermore, it discourages the normalization of wasteful behavior and sets a precedent for other establishments in the industry to adopt similar practices. Through its structured methodology, the project encourages ethical procurement (avoiding over-ordering), respect for food resources, and operational transparency.

Environmental Impact

The project's long-term effects on the environment may be the most significant. The food industry uses a lot of energy, water, and land, making it one of the most resource-intensive sectors in the world. Not only are these resources wasted when food is wasted, but landfill decomposition produces more greenhouse gas emissions. The model directly lowers the restaurant's carbon footprint by cutting down on plate waste, ingredient waste, and unmet food waste. For example, minimizing overproduction reduces the energy used in cooking, refrigeration, and dishwashing, while improved inventory control leads to less spoilage and hence, lower methane emissions from decomposing organic matter. Over time, widespread adoption of such optimization models in the hospitality industry could play a critical role in climate mitigation efforts.

To further improve the restaurant's environmental performance, fewer deliveries and less frequent procurement due to lower ingredient turnover can further cut packaging waste and emissions associated with transportation.

6.3 Possible Future Work

While the current study provides a robust and operationally sound framework for minimizing food waste through linear programming and basic time-series forecasting, there remains substantial scope for extension and refinement. The dynamic and complex nature of hospitality operations necessitate the ongoing development of more sophisticated tools and broader research initiatives.

1. Integration with Real-Time Inventory and POS Systems

There is still much room for improvement and expansion even though the current study offers a strong and practically sound foundation for reducing food waste using linear programming and simple time-series forecasting. Because hospitality operations are dynamic and complex, it is necessary to continuously develop more advanced technologies and undertake larger research projects.

2. Incorporation of Stochastic and Robust Optimization Techniques

Stochastic programming techniques may be incorporated into future model iterations to better control supply volatility and demand unpredictability. The model can generate more robust and flexible solutions by adding probabilistic distributions for factors like ingredient shelf-life variations or consumer arrival patterns. To guard against worst-case situations and lessen the susceptibility of outcomes to inaccurate data, robust optimization can also be used.

3. Multi-Objective Optimization: Balancing Cost, Nutrition, and Sustainability

The main goal of the present model is cost reduction. In reality, though, eateries also have to strike a balance between other objectives including sustainability indicators, customer pleasure, and nutritional sufficiency. Multi-objective optimization techniques could be used in future research to optimize for health, environmental, and economic results all at once. To provide a minimum caloric diversity or lessen the environmental impact of foods with high emissions (like red meat), for instance, restrictions can be applied.

4. Expansion to Other Meal Service Types and Locations

In a single hotel restaurant, the model was verified for breakfast, lunch, and dinner. The model might be expanded in future studies to incorporate other service categories such banquet events, room service, and outside catering services. Furthermore, the model's scalability and generalizability in various geographic, cultural, and economic contexts might be tested through replication across several hotel chain branches.

5. Machine Learning Integration for Forecast Enhancement

Although this study forecasted demand using classic time-series models, future iterations would benefit from including machine learning methods like random forests, gradient boosting, or recurrent neural networks (RNNs) to increase prediction accuracy. Nonlinear demand trends, the impact of outside factors (such the weather or vacations), and the interactions between dishes can all be more accurately represented by these models.

6. Life Cycle Assessment (LCA) of Waste Reduction Scenarios

Future research could include a life cycle evaluation to measure the environmental effects of waste reduction scenarios in order to further the environmental study. By addressing both the upstream (such as production and packaging) and downstream (such as waste disposal) phases of the food supply chain, this would offer a more comprehensive understanding of the advantages of the optimization model.

7. Policy and Regulatory Alignment

How this strategy can be in line with municipal and federal food waste laws may also be the subject of future study. Businesses in the hotel industry are now expected to report or cut back on their trash production in several nations. The proposed approach might act as a digital compliance tool, allowing restaurants not only optimize their operations but also meet regulatory reporting standards with minimal administrative cost.

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Appendix

Here is the GAMS code we have conducted for our project.

```
Sets
    i    "Dishes" /i1*i54/
    t    "Months" /t1*t12/;

Parameters
    D(i,t)       "Customer demand"
    Iw(i)        "Ingredient waste factor"
    Pw(i)        "Plate waste factor"
    Wf(i)           "Cost per unit of unmet food waste"
    Wi(i)        "Cost per unit of ingredient waste"
    Wp(i)        "Cost per unit of plate waste"
    K(t)         "Kitchen capacity"
    r            "Maximum allowable waste rate"
    alpha        "Minimum unmet proportion"
    v         "Minimum demand coverage ratio";
$call gdxxrw mydata.xlsx output=mydata.gdx par=D rng=Sheet1!A1:M55 rdim=1 cdim=1
Table
D(i,t) "Demand for item i at time t";
$gdxin mydata.gdx
$load D
$gdxin
display D;
$call gdxxrw mydata.xlsx output=mydata.gdx par=Iw rng=Sheet2!A1:B55 rdim=1 cdim=0
Parameter
Iw(i)    "Ingredient waste factor"
$gdxin mydata.gdx
$load Iw
$gdxin
display Iw;
$call gdxxrw mydata.xlsx output=mydata.gdx par=Pw rng=Sheet3!A1:B55 rdim=1 cdim=0
Parameter
Pw(i)    "Plate waste factor"
$gdxin mydata.gdx
$load Pw
$gdxin
display Pw;
$call gdxxrw mydata.xlsx output=mydata.gdx par=Wi rng=Sheet4!A1:B55 rdim=1 cdim=0
Parameter
Wi(i)    "Cost per serving of ingredient waste"
$gdxin mydata.gdx
$load Wi
$gdxin
display Wi;
$call gdxxrw mydata.xlsx output=mydata.gdx par=Wp rng=Sheet5!A1:B55 rdim=1 cdim=0
Parameter
Wp(i)    "Cost per serving of plate waste"
$gdxin mydata.gdx
$load Wp
$gdxin
display Wp;
$call gdxxrw mydata.xlsx output=mydata.gdx par=Wf rng=Sheet6!A1:B55 rdim=1 cdim=0
Parameter
Wf(i)   "Cost per serving of unmet food waste"
$gdxin mydata.gdx
$load Wf
$gdxin
display Wf;
```

```
parameter K(t)     "Total kitchen capacity at month t"/
t1 2500
t2 2100
t3 2250
t4 2300
t5 2420
t6 2600
t7 3000
t8 2600
t9 2550
t10 2600
t11 2300
t12 2500/;
Scalar
    r      / 0.4 /,
    alpha  / 0.2 /,
    v   / 0.85 /;

Variables
    Z         "Total waste cost"
    Q(i,t)    "Quantity prepared"
    S(i,t)    "Quantity served";

Positive Variables Q, S;

Equations
    obj              "Objective function"
    serve_limit1(i,t)
    serve_limit2(i,t)
    capacity(t)
    max_waste(t)
    min_coverage(t)
    min_unmet(i,t);

obj.. Z =e= sum((i,t), Wi(i)*Iw(i)*Q(i,t) + Wp(i)*Pw(i)*S(i,t) + Wf(i)*(Q(i,t) - S(i,t)));

serve_limit1(i,t).. S(i,t) =l= Q(i,t);
serve_limit2(i,t).. S(i,t) =l= D(i,t);

capacity(t).. sum(i, Q(i,t)) =l= K(t);

max_waste(t)..(sum(i, (Q(i,t)-S(i,t)) + Iw(i)*Q(i,t) + Pw(i)*S(i,t))) =l= r * sum(i, Q(i,t));

min_coverage(t).. sum(i, S(i,t)) =g= v * sum(i, D(i,t));

min_unmet(i,t).. Q(i,t) =g= (1 + alpha) * S(i,t);

Model waste_min /all/;
Solve waste_min using LP minimizing Z;

Display Q.l, S.l, Z.l;
```

Here is the Data we have used and the Excel file we made to make the Forecasting tables and the comparison tables.

Forecast Error Measures				Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE
				323.61	0.137	28.90	9.03%	39.202	323.87	0.177	50.05	15.4%	62.747	328.57	-4.520	50.85	15.6%	64.632	320.17	10.929	19.05	5.86%	22.913	331.48	0.253	24.90	7.99%	31.710
Date Information				Simple Naive Model					Naive Model with Linear Trend					Naive Model with Exponential Trend					Seasonal Naive Model					Seasonal Naive Model with Linear Trend				
Year	Month	Week	Breakfast Demand	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2
2021	21-Jan	Week 1	288																									
2021	21-Jan	Week 2	285	288	-3.00	3.00	1.1%	9.00																				
2021	21-Jan	Week 3	287	285	2.00	2.00	0.7%	4.00	282.00	5.00	5.00	1.74%	25.00	282.03	4.97	4.97	1.73%	24.69										
2021	21-Jan	Week 4	241	287	-46.00	46.00	19.1%	2116.00	289.00	-48.00	48.00	19.92%	2304.00	289.01	-48.01	48.01	19.92%	2305.35										
2021	21-Feb	Week 5	267	241	26.00	26.00	9.7%	676.00	195.00	72.00	72.00	26.97%	5184.00	202.37	64.63	64.63	24.20%	4176.67										
2021	21-Feb	Week 6	290	267	23.00	23.00	7.9%	529.00	293.00	-3.00	3.00	1.03%	9.00	295.80	-5.80	5.80	2.00%	33.70										
2021	21-Feb	Week 7	293	290	3.00	3.00	1.0%	9.00	313.00	-20.00	20.00	6.83%	400.00	314.98	-21.98	21.98	7.50%	483.18										
2021	21-Feb	Week 8	296	293	3.00	3.00	1.0%	9.00	296.00	0.00	0.00	0.00%	0.00	296.03	-0.03	0.03	0.01%	0.00										
2021	21-Mar	Week 9	308	296	12.00	12.00	3.9%	144.00	299.00	9.00	9.00	2.92%	81.00	299.03	8.97	8.97	2.91%	80.45										
2021	21-Mar	Week 10	293	308	-15.00	15.00	5.1%	225.00	320.00	-27.00	27.00	9.22%	729.00	320.49	-27.49	27.49	9.38%	755.51										
2021	21-Mar	Week 11	306	293	13.00	13.00	4.2%	169.00	278.00	28.00	28.00	9.15%	784.00	278.73	27.27	27.27	8.91%	743.62										
2021	21-Mar	Week 12	294	306	-12.00	12.00	4.1%	144.00	319.00	-25.00	25.00	8.50%	625.00	319.58	-25.58	25.58	8.70%	654.17										
2021	21-Apr	Week 13	300	294	6.00	6.00	2.0%	36.00	282.00	18.00	18.00	6.00%	324.00	282.47	17.53	17.53	5.84%	307.28										
2021	21-Apr	Week 14	294	300	-6.00	6.00	2.0%	36.00	306.00	-12.00	12.00	4.08%	144.00	306.12	-12.12	12.12	4.12%	146.95										
2021	21-Apr	Week 15	291	294	-3.00	3.00	1.0%	9.00	288.00	3.00	3.00	1.03%	9.00	288.12	2.88	2.88	0.99%	8.29										
2021	21-Apr	Week 16	302	291	11.00	11.00	3.6%	121.00	288.00	14.00	14.00	4.64%	196.00	288.03	13.97	13.97	4.63%	195.14										
2021	21-May	Week 17	272	302	-30.00	30.00	11.0%	900.00	313.00	-41.00	41.00	15.07%	1681.00	313.42	-41.42	41.42	15.23%	1715.27										
2021	21-May	Week 18	262	272	-10.00	10.00	3.8%	100.00	242.00	20.00	20.00	7.63%	400.00	244.98	17.02	17.02	6.50%	289.68										
2021	21-May	Week 19	299	262	37.00	37.00	12.4%	1369.00	252.00	47.00	47.00	15.72%	2209.00	252.37	46.63	46.63	15.60%	2174.58										
2021	21-May	Week 20	282	299	-17.00	17.00	6.0%	289.00	336.00	-54.00	54.00	19.15%	2916.00	341.23	-59.23	59.23	21.00%	3507.62										
2021	21-Jun	Week 21	411	282	129.00	129.00	31.4%	16641.00	265.00	146.00	146.00	35.52%	21316.00	265.97	145.03	145.03	35.29%	21034.70										
2021	21-Jun	Week 22	401	411	-10.00	10.00	2.5%	100.00	540.00	-139.00	139.00	34.66%	19321.00	599.01	-198.01	198.01	49.38%	39208.21										
2021	21-Jun	Week 23	375	401	-26.00	26.00	6.9%	676.00	391.00	-16.00	16.00	4.27%	256.00	391.24	-16.24	16.24	4.33%	263.85										
2021	21-Jun	Week 24	373	375	-2.00	2.00	0.5%	4.00	349.00	24.00	24.00	6.43%	576.00	350.69	22.31	22.31	5.98%	497.92										
2021	21-Jul	Week 25	458	373	85.00	85.00	18.6%	7225.00	371.00	87.00	87.00	19.00%	7569.00	371.01	86.99	86.99	18.99%	7567.14										
2021	21-Jul	Week 26	458	458	0.00	0.00	0.0%	0.00	543.00	-85.00	85.00	18.56%	7225.00	562.37	-104.37	104.37	22.79%	10893.09										
2021	21-Jul	Week 27	458	458	0.00	0.00	0.0%	0.00	458.00	0.00	0.00	0.00%	0.00	458.00	0.00	0.00	0.00%	0.00										
2021	21-Jul	Week 28	458	458	0.00	0.00	0.0%	0.00	458.00	0.00	0.00	0.00%	0.00	458.00	0.00	0.00	0.00%	0.00										
2021	21-Aug	Week 29	369	458	-89.00	89.00	24.1%	7921.00	458.00	-89.00	89.00	24.12%	7921.00	458.00	-89.00	89.00	24.12%	7921.00										
2021	21-Aug	Week 30	369	369	0.00	0.00	0.0%	0.00	280.00	89.00	89.00	24.12%	7921.00	297.29	71.71	71.71	19.43%	5141.64										
2021	21-Aug	Week 31	369	369	0.00	0.00	0.0%	0.00	369.00	0.00	0.00	0.00%	0.00	369.00	0.00	0.00	0.00%	0.00										
2021	21-Aug	Week 32	369	369	0.00	0.00	0.0%	0.00	369.00	0.00	0.00	0.00%	0.00	369.00	0.00	0.00	0.00%	0.00										
2021	21-Sep	Week 33	297	369	-72.00	72.00	24.2%	5184.00	369.00	-72.00	72.00	24.24%	5184.00	369.00	-72.00	72.00	24.24%	5184.00										
2021	21-Sep	Week 34	276	297	-21.00	21.00	7.6%	441.00	225.00	51.00	51.00	18.48%	2601.00	239.05	36.95	36.95	13.39%	1365.39										
2021	21-Sep	Week 35	253	276	-23.00	23.00	9.1%	529.00	255.00	-2.00	2.00	0.79%	4.00	256.48	-3.48	3.48	1.38%	12.14										
2021	21-Sep	Week 36	294	253	41.00	41.00	13.9%	1681.00	230.00	64.00	64.00	21.77%	4096.00	231.92	62.08	62.08	21.12%	3854.34										
2021	21-Oct	Week 37	260	294	-34.00	34.00	13.1%	1156.00	335.00	-75.00	75.00	28.85%	5625.00	341.64	-81.64	81.64	31.40%	6665.79										
2021	21-Oct	Week 38	281	260	21.00	21.00	7.5%	441.00	226.00	55.00	55.00	19.57%	3025.00	229.93	51.07	51.07	18.17%	2607.94										
2021	21-Oct	Week 39	258	281	-23.00	23.00	8.9%	529.00	302.00	-44.00	44.00	17.05%	1936.00	303.70	-45.70	45.70	17.71%	2088.14										
2021	21-Oct	Week 40	294	258	36.00	36.00	12.2%	1296.00	235.00	59.00	59.00	20.07%	3481.00	236.88	57.12	57.12	19.43%	3262.40										
2021	21-Nov	Week 41	280	294	-14.00	14.00	5.0%	196.00	330.00	-50.00	50.00	17.86%	2500.00	335.02	-55.02	55.02	19.65%	3027.56										
2021	21-Nov	Week 42	261	280	-19.00	19.00	7.3%	361.00	266.00	-5.00	5.00	1.92%	25.00	266.67	-5.67	5.67	2.17%	32.11										
2021	21-Nov	Week 43	252	261	-9.00	9.00	3.6%	81.00	242.00	10.00	10.00	3.97%	100.00	243.29	8.71	8.71	3.46%	75.88										
2021	21-Nov	Week 44	260	252	8.00	8.00	3.1%	64.00	243.00	17.00	17.00	6.54%	289.00	243.31	16.69	16.69	6.42%	278.54										
2021	21-Dec	Week 45	230	260	-30.00	30.00	13.0%	900.00	268.00	-38.00	38.00	16.52%	1444.00	268.25	-38.25	38.25	16.63%	1463.37										
2021	21-Dec	Week 46	264	230	34.00	34.00	12.9%	1156.00	200.00	64.00	64.00	24.24%	4096.00	203.46	60.54	60.54	22.93%	3664.91										
2021	21-Dec	Week 47	277	264	13.00	13.00	4.7%	169.00	298.00	-21.00	21.00	7.58%	441.00	303.03	-26.03	26.03	9.40%	677.36										
2021	21-Dec	Week 48	232	277	-45.00	45.00	19.4%	2025.00	290.00	-58.00	58.00	25.00%	3364.00	290.64	-58.64	58.64	25.28%	3438.67										
2022	22-Jan	Week 49	278	232	46.00	46.00	16.5%	2116.00	187.00	91.00	91.00	32.73%	8281.00	194.31	83.69	83.69	30.10%	7003.94	288.00	-10.00	10.00	3.60%	100.00					
2022	22-Jan	Week 50	310	278	32.00	32.00	10.3%	1024.00	324.00	-14.00	14.00	4.52%	196.00	333.12	-23.12	23.12	7.46%	534.57	285.00	25.00	25.00	8.06%	625.00	275.00	35.00	35.00	11.3%	1225.00
2022	22-Jan	Week 51	283	310	-27.00	27.00	9.5%	729.00	342.00	-59.00	59.00	20.85%	3481.00	345.68	-62.68	62.68	22.15%	3929.22	287.00	-4.00	4.00	1.41%	16.00	312.00	-29.00	29.00	10.2%	841.00
2022	22-Jan	Week 52	263	283	-20.00	20.00	7.6%	400.00	256.00	7.00	7.00	2.66%	49.00	258.35	4.65	4.65	1.77%	21.61	241.00	22.00	22.00	8.37%	484.00	237.00	26.00	26.00	9.9%	676.00
2022	22-Feb	Week 53	277	263	14.00	14.00	5.1%	196.00	243.00	34.00	34.00	12.27%	1156.00	244.41	32.59	32.59	11.76%	1061.88	267.00	10.00	10.00	3.61%	100.00	289.00	-12.00	12.00	4.3%	144.00
2022	22-Feb	Week 54	326	277	49.00	49.00	15.0%	2401.00	291.00	35.00	35.00	10.74%	1225.00	291.75	34.25	34.25	10.51%	1173.39	290.00	36.00	36.00	11.04%	1296.00	300.00	26.00	26.00	8.0%	676.00
2022	22-Feb	Week 55	283	326	-43.00	43.00	15.2%	1849.00	375.00	-92.00	92.00	32.51%	8464.00	383.67	-100.67	100.67	35.57%	10134.02	293.00	-10.00	10.00	3.53%	100.00	329.00	-46.00	46.00	16.3%	2116.00
2022	22-Feb	Week 56	294	283	11.00	11.00	3.7%	121.00	240.00	54.00	54.00	18.37%	2916.00	245.67	48.33	48.33	16.44%	2335.62	296.00	-2.00	2.00	0.68%	4.00	286.00	8.00	8.00	2.7%	64.00
2022	22-Mar	Week 57	328	294	34.00	34.00	10.4%	1156.00	305.00	23.00	23.00	7.01%	529.00	305.43	22.57	22.57	6.88%	509.51	308.00	20.00	20.00	6.10%	400.00	306.00	22.00	22.00	6.7%	484.00
2022	22-Mar	Week 58	282	328	-46.00	46.00	16.3%	2116.00	362.00	-80.00	80.00	28.37%	6400.00	365.93	-83.93	83.93	29.76%	7044.58	293.00	-11.00	11.00	3.90%	121.00	313.00	-31.00	31.00	11.0%	961.00
2022	22-Mar	Week 59	305	282	23.00	23.00	7.5%	529.00	236.00	69.00	69.00	22.62%	4761.00	242.45	62.55	62.55	20.51%	3912.35	306.00	-1.00	1.00	0.33%	1.00	295.00	10.00	10.00	3.3%	100.00
2022	22-Mar	Week 60	315	305	10.00	10.00	3.2%	100.00	328.00	-13.00	13.00	4.13%	169.00	329.88	-14.88	14.88	4.72%	221.29	294.00	21.00	21.00	6.67%	441.00	293.00	22.00	22.00	7.0%	484.00
2022	22-Apr	Week 61	321	315	6.00	6.00	1.9%	36.00	325.00	-4.00	4.00	1.25%	16.00	325.33	-4.33	4.33	1.35%	18.73	300.00	21.00	21.00	6.54%	441.00	321.00	0.00	0.00	0.0%	0.00
2022	22-Apr	Week 62	306	321	-15.00	15.00	4.9%	225.00	327.00	-21.00	21.00	6.86%	441.00	327.11	-21.11	21.11	6.90%	445.81	294.00	12.00	12.00	3.92%	144.00	315.00	-9.00	9.00	2.9%	81.00
2022	22-Apr	Week 63	286	306	-20.00	20.00	7.0%	400.00	291.00	-5.00	5.00	1.75%	25.00	291.70	-5.70	5.70	1.99%	32.50	291.00	-5.00	5.00	1.75%	25.00	303.00	-17.00	17.00	5.9%	289.00
2022	22-Apr	Week 64	309	286	23.00	23.00	7.4%	529.00	266.00	43.00	43.00	13.92%	1849.00	267.31	41.69	41.69	13.49%	1738.29	302.00	7.00	7.00	2.27%	49.00	297.00	12.00	12.00	3.9%	144.00

Forecast Error Measures				Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE
				447.00	1.092	25.63	5.81%	37.002	448.50	0.169	43.17	9.8%	55.872
Date Information				Simple Naive Model					Naive Model with Linear Trend				
Year	Month	Week	Lunch Demand	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2
2021	21-Jan	Week 1	390										
2021	21-Jan	Week 2	384	390	-6.00	6.00	1.6%	36.00					
2021	21-Jan	Week 3	351	384	-33.00	33.00	9.4%	1089.00	378.00	-27.00	27.00	7.69%	729.00
2021	21-Jan	Week 4	347	351	-4.00	4.00	1.2%	16.00	318.00	29.00	29.00	8.36%	841.00
2021	21-Feb	Week 5	385	347	38.00	38.00	9.9%	1444.00	343.00	42.00	42.00	10.91%	1764.00
2021	21-Feb	Week 6	339	385	-46.00	46.00	13.6%	2116.00	423.00	-84.00	84.00	24.78%	7056.00
2021	21-Feb	Week 7	339	339	0.00	0.00	0.0%	0.00	293.00	46.00	46.00	13.57%	2116.00
2021	21-Feb	Week 8	340	339	1.00	1.00	0.3%	1.00	339.00	1.00	1.00	0.29%	1.00
2021	21-Mar	Week 9	344	340	4.00	4.00	1.2%	16.00	341.00	3.00	3.00	0.87%	9.00
2021	21-Mar	Week 10	354	344	10.00	10.00	2.8%	100.00	348.00	6.00	6.00	1.69%	36.00
2021	21-Mar	Week 11	366	354	12.00	12.00	3.3%	144.00	364.00	2.00	2.00	0.55%	4.00
2021	21-Mar	Week 12	332	366	-34.00	34.00	10.2%	1156.00	378.00	-46.00	46.00	13.86%	2116.00
2021	21-Apr	Week 13	426	332	94.00	94.00	22.1%	8836.00	298.00	128.00	128.00	30.05%	16384.00
2021	21-Apr	Week 14	400	426	-26.00	26.00	6.5%	676.00	520.00	-120.00	120.00	30.00%	14400.00
2021	21-Apr	Week 15	390	400	-10.00	10.00	2.6%	100.00	374.00	16.00	16.00	4.10%	256.00
2021	21-Apr	Week 16	378	390	-12.00	12.00	3.2%	144.00	380.00	-2.00	2.00	0.53%	4.00
2021	21-May	Week 17	412	378	34.00	34.00	8.3%	1156.00	366.00	46.00	46.00	11.17%	2116.00
2021	21-May	Week 18	390	412	-22.00	22.00	5.6%	484.00	446.00	-56.00	56.00	14.36%	3136.00
2021	21-May	Week 19	379	390	-11.00	11.00	2.9%	121.00	368.00	11.00	11.00	2.90%	121.00
2021	21-May	Week 20	422	379	43.00	43.00	10.2%	1849.00	368.00	54.00	54.00	12.80%	2916.00
2021	21-Jun	Week 21	513	422	91.00	91.00	17.7%	8281.00	465.00	48.00	48.00	9.36%	2304.00
2021	21-Jun	Week 22	553	513	40.00	40.00	7.2%	1600.00	604.00	-51.00	51.00	9.22%	2601.00
2021	21-Jun	Week 23	516	553	-37.00	37.00	7.2%	1369.00	593.00	-77.00	77.00	14.92%	5929.00
2021	21-Jun	Week 24	538	516	22.00	22.00	4.1%	484.00	479.00	59.00	59.00	10.97%	3481.00
2021	21-Jul	Week 25	577	538	39.00	39.00	6.8%	1521.00	560.00	17.00	17.00	2.95%	289.00
2021	21-Jul	Week 26	577	577	0.00	0.00	0.0%	0.00	616.00	-39.00	39.00	6.76%	1521.00
2021	21-Jul	Week 27	577	577	0.00	0.00	0.0%	0.00	577.00	0.00	0.00	0.00%	0.00
2021	21-Jul	Week 28	577	577	0.00	0.00	0.0%	0.00	577.00	0.00	0.00	0.00%	0.00
2021	21-Aug	Week 29	483	577	-94.00	94.00	19.5%	8836.00	577.00	-94.00	94.00	19.46%	8836.00
2021	21-Aug	Week 30	492	483	9.00	9.00	1.8%	81.00	389.00	103.00	103.00	20.93%	10609.00
2021	21-Aug	Week 31	524	492	32.00	32.00	6.1%	1024.00	501.00	23.00	23.00	4.39%	529.00
2021	21-Aug	Week 32	482	524	-42.00	42.00	8.7%	1764.00	556.00	-74.00	74.00	15.35%	5476.00
2021	21-Sep	Week 33	449	482	-33.00	33.00	7.3%	1089.00	440.00	9.00	9.00	2.00%	81.00
2021	21-Sep	Week 34	481	449	32.00	32.00	6.7%	1024.00	416.00	65.00	65.00	13.51%	4225.00
2021	21-Sep	Week 35	490	481	9.00	9.00	1.8%	81.00	513.00	-23.00	23.00	4.69%	529.00
2021	21-Sep	Week 36	484	490	-6.00	6.00	1.2%	36.00	499.00	-15.00	15.00	3.10%	225.00
2021	21-Oct	Week 37	413	484	-71.00	71.00	17.2%	5041.00	478.00	-65.00	65.00	15.74%	4225.00
2021	21-Oct	Week 38	392	413	-21.00	21.00	5.4%	441.00	342.00	50.00	50.00	12.76%	2500.00
2021	21-Oct	Week 39	387	392	-5.00	5.00	1.3%	25.00	371.00	16.00	16.00	4.13%	256.00
2021	21-Oct	Week 40	431	387	44.00	44.00	10.2%	1936.00	382.00	49.00	49.00	11.37%	2401.00
2021	21-Nov	Week 41	361	431	-70.00	70.00	19.4%	4900.00	475.00	-114.00	114.00	31.58%	12996.00
2021	21-Nov	Week 42	341	361	-20.00	20.00	5.9%	400.00	291.00	50.00	50.00	14.66%	2500.00
2021	21-Nov	Week 43	370	341	29.00	29.00	7.8%	841.00	321.00	49.00	49.00	13.24%	2401.00
2021	21-Nov	Week 44	337	370	-33.00	33.00	9.8%	1089.00	399.00	-62.00	62.00	18.40%	3844.00
2021	21-Dec	Week 45	338	337	1.00	1.00	0.3%	1.00	304.00	34.00	34.00	10.06%	1156.00
2021	21-Dec	Week 46	338	338	0.00	0.00	0.0%	0.00	339.00	-1.00	1.00	0.30%	1.00
2021	21-Dec	Week 47	338	338	0.00	0.00	0.0%	0.00	338.00	0.00	0.00	0.00%	0.00
2021	21-Dec	Week 48	338	338	0.00	0.00	0.0%	0.00	338.00	0.00	0.00	0.00%	0.00
2022	22-Jan	Week 49	371	338	33.00	33.00	8.9%	1089.00	338.00	33.00	33.00	8.89%	1089.00
2022	22-Jan	Week 50	403	371	32.00	32.00	7.9%	1024.00	404.00	-1.00	1.00	0.25%	1.00
2022	22-Jan	Week 51	393	403	-10.00	10.00	2.5%	100.00	435.00	-42.00	42.00	10.69%	1764.00
2022	22-Jan	Week 52	394	393	1.00	1.00	0.3%	1.00	383.00	11.00	11.00	2.79%	121.00
2022	22-Feb	Week 53	358	394	-36.00	36.00	10.1%	1296.00	395.00	-37.00	37.00	10.34%	1369.00
2022	22-Feb	Week 54	385	358	27.00	27.00	7.0%	729.00	322.00	63.00	63.00	16.36%	3969.00
2022	22-Feb	Week 55	373	385	-12.00	12.00	3.2%	144.00	412.00	-39.00	39.00	10.46%	1521.00
2022	22-Feb	Week 56	371	373	-2.00	2.00	0.5%	4.00	361.00	10.00	10.00	2.70%	100.00
2022	22-Mar	Week 57	364	371	-7.00	7.00	1.9%	49.00	369.00	-5.00	5.00	1.37%	25.00
2022	22-Mar	Week 58	342	364	-22.00	22.00	6.4%	484.00	357.00	-15.00	15.00	4.39%	225.00
2022	22-Mar	Week 59	384	342	42.00	42.00	10.9%	1764.00	320.00	64.00	64.00	16.67%	4096.00

			Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE	Mean	ME	MAE	MAPE	RMSE
			451.57	-2.984	43.54	9.8%	56.933	439.19	24.333	27.07	5.92%	31.914	464.06	8.578	25.30	5.80%	31.980
Date Information			Naive Model with Exponential Trend					Seasonal Naive Model					Seasonal Naive Model with Linear Trend				
Year	Month	Week	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2
2021	21-Jan	Week 1															
2021	21-Jan	Week 2															
2021	21-Jan	Week 3	378.09	-27.09	27.09	7.72%	733.99										
2021	21-Jan	Week 4	320.84	26.16	26.16	7.54%	684.56										
2021	21-Feb	Week 5	343.05	41.95	41.95	10.90%	1760.17										
2021	21-Feb	Week 6	427.16	-88.16	88.16	26.01%	7772.43										
2021	21-Feb	Week 7	298.50	40.50	40.50	11.95%	1640.57										
2021	21-Feb	Week 8	339.00	1.00	1.00	0.29%	1.00										
2021	21-Mar	Week 9	341.00	3.00	3.00	0.87%	8.98										
2021	21-Mar	Week 10	348.05	5.95	5.95	1.68%	35.44										
2021	21-Mar	Week 11	364.29	1.71	1.71	0.47%	2.92										
2021	21-Mar	Week 12	378.41	-46.41	46.41	13.98%	2153.59										
2021	21-Apr	Week 13	301.16	124.84	124.84	29.31%	15585.41										
2021	21-Apr	Week 14	546.61	-146.61	146.61	36.65%	21495.00										
2021	21-Apr	Week 15	375.59	14.41	14.41	3.70%	207.74										
2021	21-Apr	Week 16	380.25	-2.25	2.25	0.60%	5.06										
2021	21-May	Week 17	366.37	45.63	45.63	11.08%	2082.17										
2021	21-May	Week 18	449.06	-59.06	59.06	15.14%	3487.87										
2021	21-May	Week 19	369.17	9.83	9.83	2.59%	96.54										
2021	21-May	Week 20	368.31	53.69	53.69	12.72%	2882.59										
2021	21-Jun	Week 21	469.88	43.12	43.12	8.41%	1859.45										
2021	21-Jun	Week 22	623.62	-70.62	70.62	12.77%	4987.64										
2021	21-Jun	Week 23	596.12	-80.12	80.12	15.53%	6419.04										
2021	21-Jun	Week 24	481.48	56.52	56.52	10.51%	3195.01										
2021	21-Jul	Week 25	560.94	16.06	16.06	2.78%	257.99										
2021	21-Jul	Week 26	618.83	-41.83	41.83	7.25%	1749.51										
2021	21-Jul	Week 27	577.00	0.00	0.00	0.00%	0.00										
2021	21-Jul	Week 28	577.00	0.00	0.00	0.00%	0.00										
2021	21-Aug	Week 29	577.00	-94.00	94.00	19.46%	8836.00										
2021	21-Aug	Week 30	404.31	87.69	87.69	17.82%	7688.89										
2021	21-Aug	Week 31	501.17	22.83	22.83	4.36%	521.31										
2021	21-Aug	Week 32	558.08	-76.08	76.08	15.78%	5788.36										
2021	21-Sep	Week 33	443.37	5.63	5.63	1.25%	31.74										
2021	21-Sep	Week 34	418.26	62.74	62.74	13.04%	3936.39										
2021	21-Sep	Week 35	515.28	-25.28	25.28	5.16%	639.11										
2021	21-Sep	Week 36	499.17	-15.17	15.17	3.13%	230.08										
2021	21-Oct	Week 37	478.07	-65.07	65.07	15.76%	4234.56										
2021	21-Oct	Week 38	352.42	39.58	39.58	10.10%	1566.95										
2021	21-Oct	Week 39	372.07	14.93	14.93	3.86%	222.97										
2021	21-Oct	Week 40	382.06	48.94	48.94	11.35%	2394.75										
2021	21-Nov	Week 41	480.00	-119.00	119.00	32.96%	14161.61										
2021	21-Nov	Week 42	302.37	38.63	38.63	11.33%	1492.36										
2021	21-Nov	Week 43	322.11	47.89	47.89	12.94%	2293.64										
2021	21-Nov	Week 44	401.47	-64.47	64.47	19.13%	4155.98										
2021	21-Dec	Week 45	306.94	31.06	31.06	9.19%	964.52										
2021	21-Dec	Week 46	339.00	-1.00	1.00	0.30%	1.01										
2021	21-Dec	Week 47	338.00	0.00	0.00	0.00%	0.00										
2021	21-Dec	Week 48	338.00	0.00	0.00	0.00%	0.00										
2022	22-Jan	Week 49	338.00	33.00	33.00	8.89%	1089.00	390.00	-19.00	19.00	5.12%	361.00					
2022	22-Jan	Week 50	407.22	-4.22	4.22	1.05%	17.82	384.00	19.00	19.00	4.71%	361.00	365.00	38.00	38.00	9.4%	1444.00
2022	22-Jan	Week 51	437.76	-44.76	44.76	11.39%	2003.47	351.00	42.00	42.00	10.69%	1764.00	370.00	23.00	23.00	5.9%	529.00
2022	22-Jan	Week 52	383.25	10.75	10.75	2.73%	115.60	347.00	47.00	47.00	11.93%	2209.00	389.00	5.00	5.00	1.3%	25.00
2022	22-Feb	Week 53	395.00	-37.00	37.00	10.34%	1369.19	385.00	-27.00	27.00	7.54%	729.00	432.00	-74.00	74.00	20.7%	5476.00
2022	22-Feb	Week 54	325.29	59.71	59.71	15.51%	3565.36	339.00	46.00	46.00	11.95%	2116.00	312.00	73.00	73.00	19.0%	5329.00
2022	22-Feb	Week 55	414.04	-41.04	41.04	11.00%	1683.98	339.00	34.00	34.00	9.12%	1156.00	385.00	-12.00	12.00	3.2%	144.00
2022	22-Feb	Week 56	361.37	9.63	9.63	2.59%	92.66	340.00	31.00	31.00	8.36%	961.00	374.00	-3.00	3.00	0.8%	9.00
2022	22-Mar	Week 57	369.01	-5.01	5.01	1.30%	25.11	344.00	20.00	20.00	5.49%	400.00	375.00	-11.00	11.00	3.0%	121.00
2022	22-Mar	Week 58	357.13	-15.13	15.13	4.42%	228.98	354.00	-12.00	12.00	3.51%	144.00	374.00	-32.00	32.00	9.4%	1024.00
2022	22-Mar	Week 59	321.33	62.67	62.67	16.32%	3927.57	366.00	18.00	18.00	4.69%	324.00	354.00	30.00	30.00	7.8%	900.00

Forecast Error Measures	Mean	ME	MAE	MAPE	RMSE
Simple Naïve Model	327.77	0.275	25.82	8.11%	33.640
Naïve Model with Linear Trend	328.27	0.254	42.73	13.5%	52.533
Naïve Model with Exponential Trend	331.68	-3.153	42.62	13.4%	52.103
Seasonal Naïve Model	322.00	14.643	20.90	6.25%	26.105
Seasonal Naïve Model with Linear Trend	330.00	0.108	30.18	9.22%	35.741

Date Information				Simple Naïve Model				
Year	Month	Time	Dinner Demand	Forecast	Error	|Error|	|Error|%	Error^2
2021	21-Jan	Week 1	292					
2021	21-Jan	Week 2	266	292	-26.00	26.00	9.8%	676.00
2021	21-Jan	Week 3	263	266	-3.00	3.00	1.1%	9.00
2021	21-Jan	Week 4	246	263	-17.00	17.00	6.9%	289.00
2021	21-Feb	Week 5	296	246	50.00	50.00	16.9%	2500.00
2021	21-Feb	Week 6	274	296	-22.00	22.00	8.0%	484.00
2021	21-Feb	Week 7	258	274	-16.00	16.00	6.2%	256.00
2021	21-Feb	Week 8	278	258	20.00	20.00	7.2%	400.00
2021	21-Mar	Week 9	293	278	15.00	15.00	5.1%	225.00
2021	21-Mar	Week 10	278	293	-15.00	15.00	5.4%	225.00
2021	21-Mar	Week 11	285	278	7.00	7.00	2.5%	49.00
2021	21-Mar	Week 12	262	285	-23.00	23.00	8.8%	529.00
2021	21-Apr	Week 13	291	262	29.00	29.00	10.0%	841.00
2021	21-Apr	Week 14	301	291	10.00	10.00	3.3%	100.00
2021	21-Apr	Week 15	287	301	-14.00	14.00	4.9%	196.00
2021	21-Apr	Week 16	275	287	-12.00	12.00	4.4%	144.00
2021	21-May	Week 17	273	275	-2.00	2.00	0.7%	4.00
2021	21-May	Week 18	299	273	26.00	26.00	8.7%	676.00
2021	21-May	Week 19	319	299	20.00	20.00	6.3%	400.00
2021	21-May	Week 20	315	319	-4.00	4.00	1.3%	16.00
2021	21-Jun	Week 21	365	315	50.00	50.00	13.7%	2500.00
2021	21-Jun	Week 22	405	365	40.00	40.00	9.9%	1600.00
2021	21-Jun	Week 23	386	405	-19.00	19.00	4.9%	361.00
2021	21-Jun	Week 24	404	386	18.00	18.00	4.5%	324.00
2021	21-Jul	Week 25	432	404	28.00	28.00	6.5%	784.00
2021	21-Jul	Week 26	442	432	10.00	10.00	2.3%	100.00
2021	21-Jul	Week 27	457	442	15.00	15.00	3.3%	225.00
2021	21-Jul	Week 28	435	457	-22.00	22.00	5.1%	484.00
2021	21-Aug	Week 29	331	435	-104.00	104.00	31.4%	10816.00
2021	21-Aug	Week 30	363	331	32.00	32.00	8.8%	1024.00
2021	21-Aug	Week 31	363	363	0.00	0.00	0.0%	0.00
2021	21-Aug	Week 32	377	363	14.00	14.00	3.7%	196.00
2021	21-Sep	Week 33	283	377	-94.00	94.00	33.2%	8836.00
2021	21-Sep	Week 34	302	283	19.00	19.00	6.3%	361.00
2021	21-Sep	Week 35	328	302	26.00	26.00	7.9%	676.00
2021	21-Sep	Week 36	290	328	-38.00	38.00	13.1%	1444.00
2021	21-Oct	Week 37	320	290	30.00	30.00	9.4%	900.00
2021	21-Oct	Week 38	340	320	20.00	20.00	5.9%	400.00
2021	21-Oct	Week 39	317	340	-23.00	23.00	7.3%	529.00
2021	21-Oct	Week 40	344	317	27.00	27.00	7.8%	729.00
2021	21-Nov	Week 41	259	344	-85.00	85.00	32.8%	7225.00
2021	21-Nov	Week 42	239	259	-20.00	20.00	8.4%	400.00
2021	21-Nov	Week 43	241	239	2.00	2.00	0.8%	4.00
2021	21-Nov	Week 44	281	241	40.00	40.00	14.2%	1600.00
2021	21-Dec	Week 45	251	281	-30.00	30.00	12.0%	900.00
2021	21-Dec	Week 46	244	251	-7.00	7.00	2.9%	49.00
2021	21-Dec	Week 47	244	244	0.00	0.00	0.0%	0.00
2021	21-Dec	Week 48	227	244	-17.00	17.00	7.5%	289.00
2022	22-Jan	Week 49	275	227	48.00	48.00	17.5%	2304.00
2022	22-Jan	Week 50	304	275	29.00	29.00	9.5%	841.00
2022	22-Jan	Week 51	263	304	-41.00	41.00	15.6%	1681.00
2022	22-Jan	Week 52	278	263	15.00	15.00	5.4%	225.00
2022	22-Feb	Week 53	304	278	26.00	26.00	8.6%	676.00
2022	22-Feb	Week 54	271	304	-33.00	33.00	12.2%	1089.00
2022	22-Feb	Week 55	308	271	37.00	37.00	12.0%	1369.00
2022	22-Feb	Week 56	278	308	-30.00	30.00	10.8%	900.00
2022	22-Mar	Week 57	293	278	15.00	15.00	5.1%	225.00
2022	22-Mar	Week 58	299	293	6.00	6.00	2.0%	36.00
2022	22-Mar	Week 59	289	299	-10.00	10.00	3.5%	100.00

	Naïve Model with Linear Trend					Naïve Model with Exponential Trend				
Time	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2
Week 1										
Week 2										
Week 3	240.00	23.00	23.00	8.75%	529.00	242.32	20.68	20.68	7.86%	427.87
Week 4	260.00	-14.00	14.00	5.69%	196.00	260.03	-14.03	14.03	5.70%	196.95
Week 5	229.00	67.00	67.00	22.64%	4489.00	230.10	65.90	65.90	22.26%	4342.96
Week 6	346.00	-72.00	72.00	26.28%	5184.00	356.16	-82.16	82.16	29.99%	6750.69
Week 7	252.00	6.00	6.00	2.33%	36.00	253.64	4.36	4.36	1.69%	19.05
Week 8	242.00	36.00	36.00	12.95%	1296.00	242.93	35.07	35.07	12.61%	1229.60
Week 9	298.00	-5.00	5.00	1.71%	25.00	299.55	-6.55	6.55	2.24%	42.91
Week 10	308.00	-30.00	30.00	10.79%	900.00	308.81	-30.81	30.81	11.08%	949.22
Week 11	263.00	22.00	22.00	7.72%	484.00	263.77	21.23	21.23	7.45%	450.80
Week 12	292.00	-30.00	30.00	11.45%	900.00	292.18	-30.18	30.18	11.52%	910.61
Week 13	239.00	52.00	52.00	17.87%	2704.00	240.86	50.14	50.14	17.23%	2514.41
Week 14	320.00	-19.00	19.00	6.31%	361.00	323.21	-22.21	22.21	7.38%	493.28
Week 15	311.00	-24.00	24.00	8.36%	576.00	311.34	-24.34	24.34	8.48%	592.61
Week 16	273.00	2.00	2.00	0.73%	4.00	273.65	1.35	1.35	0.49%	1.82
Week 17	263.00	10.00	10.00	3.66%	100.00	263.50	9.50	9.50	3.48%	90.22
Week 18	271.00	28.00	28.00	9.36%	784.00	271.01	27.99	27.99	9.36%	783.19
Week 19	325.00	-6.00	6.00	1.88%	36.00	327.48	-8.48	8.48	2.66%	71.85
Week 20	339.00	-24.00	24.00	7.62%	576.00	340.34	-25.34	25.34	8.04%	642.08
Week 21	311.00	54.00	54.00	14.79%	2916.00	311.05	53.95	53.95	14.78%	2910.59
Week 22	415.00	-10.00	10.00	2.47%	100.00	422.94	-17.94	17.94	4.43%	321.72
Week 23	445.00	-59.00	59.00	15.28%	3481.00	449.38	-63.38	63.38	16.42%	4017.48
Week 24	367.00	37.00	37.00	9.16%	1369.00	367.89	36.11	36.11	8.94%	1303.83
Week 25	422.00	10.00	10.00	2.31%	100.00	422.84	9.16	9.16	2.12%	83.92
Week 26	460.00	-18.00	18.00	4.07%	324.00	461.94	-19.94	19.94	4.51%	397.63
Week 27	452.00	5.00	5.00	1.09%	25.00	452.23	4.77	4.77	1.04%	22.74
Week 28	472.00	-37.00	37.00	8.51%	1369.00	472.51	-37.51	37.51	8.62%	1406.93
Week 29	413.00	-82.00	82.00	24.77%	6724.00	414.06	-83.06	83.06	25.09%	6898.81
Week 30	227.00	136.00	136.00	37.47%	18496.00	251.86	111.14	111.14	30.62%	12351.13
Week 31	395.00	-32.00	32.00	8.82%	1024.00	398.09	-35.09	35.09	9.67%	1231.56
Week 32	363.00	14.00	14.00	3.71%	196.00	363.00	14.00	14.00	3.71%	196.00
Week 33	391.00	-108.00	108.00	38.16%	11664.00	391.54	-108.54	108.54	38.35%	11780.92
Week 34	189.00	113.00	113.00	37.42%	12769.00	212.44	89.56	89.56	29.66%	8021.41
Week 35	321.00	7.00	7.00	2.13%	49.00	322.28	5.72	5.72	1.75%	32.77
Week 36	354.00	-64.00	64.00	22.07%	4096.00	356.24	-66.24	66.24	22.84%	4387.53
Week 37	252.00	68.00	68.00	21.25%	4624.00	256.40	63.60	63.60	19.87%	4044.65
Week 38	350.00	-10.00	10.00	2.94%	100.00	353.10	-13.10	13.10	3.85%	171.70
Week 39	360.00	-43.00	43.00	13.56%	1849.00	361.25	-44.25	44.25	13.96%	1958.06
Week 40	294.00	50.00	50.00	14.53%	2500.00	295.56	48.44	48.44	14.08%	2346.83
Week 41	371.00	-112.00	112.00	43.24%	12544.00	373.30	-114.30	114.30	44.13%	13064.42
Week 42	174.00	65.00	65.00	27.20%	4225.00	195.00	44.00	44.00	18.41%	1935.74
Week 43	219.00	22.00	22.00	9.13%	484.00	220.54	20.46	20.46	8.49%	418.43
Week 44	243.00	38.00	38.00	13.52%	1444.00	243.02	37.98	37.98	13.52%	1442.73
Week 45	321.00	-70.00	70.00	27.89%	4900.00	327.64	-76.64	76.64	30.53%	5873.54
Week 46	221.00	23.00	23.00	9.43%	529.00	224.20	19.80	19.80	8.11%	391.93
Week 47	237.00	7.00	7.00	2.87%	49.00	237.20	6.80	6.80	2.79%	46.31
Week 48	244.00	-17.00	17.00	7.49%	289.00	244.00	-17.00	17.00	7.49%	289.00
Week 49	210.00	65.00	65.00	23.64%	4225.00	211.18	63.82	63.82	23.21%	4072.43
Week 50	323.00	-19.00	19.00	6.25%	361.00	333.15	-29.15	29.15	9.59%	849.71
Week 51	333.00	-70.00	70.00	26.62%	4900.00	336.06	-73.06	73.06	27.78%	5337.50
Week 52	222.00	56.00	56.00	20.14%	3136.00	227.53	50.47	50.47	18.15%	2547.26
Week 53	293.00	11.00	11.00	3.62%	121.00	293.86	10.14	10.14	3.34%	102.91
Week 54	330.00	-59.00	59.00	21.77%	3481.00	332.43	-61.43	61.43	22.67%	3773.85
Week 55	238.00	70.00	70.00	22.73%	4900.00	241.58	66.42	66.42	21.56%	4411.32
Week 56	345.00	-67.00	67.00	24.10%	4489.00	350.05	-72.05	72.05	25.92%	5191.44
Week 57	248.00	45.00	45.00	15.36%	2025.00	250.92	42.08	42.08	14.36%	1770.55
Week 58	308.00	-9.00	9.00	3.01%	81.00	308.81	-9.81	9.81	3.28%	96.22
Week 59	305.00	-16.00	16.00	5.54%	256.00	305.12	-16.12	16.12	5.58%	259.95

	Seasonal Naïve Model					Seasonal Naïve Model with Linear Trend				
Time	Forecast	Error	|Error|	|Error|%	Error^2	Forecast	Error	|Error|	|Error|%	Error^2
Week 49	292.00	-17.00	17.00	6.18%	289.00					
Week 50	266.00	38.00	38.00	12.50%	1444.00	249.00	55.00	55.00	18.1%	3025.00
Week 51	263.00	0.00	0.00	0.00%	0.00	301.00	-38.00	38.00	14.4%	1444.00
Week 52	246.00	32.00	32.00	11.51%	1024.00	246.00	32.00	32.00	11.5%	1024.00
Week 53	296.00	8.00	8.00	2.63%	64.00	328.00	-24.00	24.00	7.9%	576.00
Week 54	274.00	-3.00	3.00	1.11%	9.00	282.00	-11.00	11.00	4.1%	121.00
Week 55	258.00	50.00	50.00	16.23%	2500.00	255.00	53.00	53.00	17.2%	2809.00
Week 56	278.00	0.00	0.00	0.00%	0.00	328.00	-50.00	50.00	18.0%	2500.00
Week 57	293.00	0.00	0.00	0.00%	0.00	293.00	0.00	0.00	0.0%	0.00
Week 58	278.00	21.00	21.00	7.02%	441.00	278.00	21.00	21.00	7.0%	441.00
Week 59	285.00	4.00	4.00	1.38%	16.00	306.00	-17.00	17.00	5.9%	289.00