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Optimizing Bakery Production: A Goal Programming Approach

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ABSTRACT

Bakery production involves a myriad of decisions ranging from ingredient sourcing to product assortment, all aimed at meeting customer demands while maintaining profitability. Goal programming offers a powerful framework to navigate the complexities of bakery production by simultaneously addressing multiple objectives, such as maximizing profit, minimizing costs, and ensuring product quality. This abstract explores the application of goal programming techniques in the context of bakery production. By formulating the bakery's objectives into a mathematical model, goal programming enables decision-makers to find optimal solutions that balance conflicting goals. Key considerations include resource allocation, production scheduling, inventory management, and product diversification. Through a case study or simulation, this abstract demonstrates how goal programming can be used to enhance bakery operations. By considering constraints such as production capacity, ingredient availability, and market demand, the model identifies production plans that optimize the bakery's performance while satisfying various stakeholders' preferences. In addition, this abstract discusses the potential benefits and challenges of applying goal programming in small industries such as bakery production. Three goals are considered - maximizing daily sales profit, minimizing overtime and optimal utilization of the machines used in the production of bakery products. The Longo Optimizer solver indicated that SMEs may need to review their profit goals in line with their policy on overtime and time utilization of their machines.

KEYWORDS

Bakery Production, Goal Programming, Optimization, Multi-objective Decision Making Resource Allocation, Production Scheduling, Inventory Management, Product Diversification, Profit Maximization, Cost Minimization

INTRODUCTION

Bakery production represents a dynamic and multifaceted industry where success hinges upon the ability to balance various objectives, including maximizing profitability, minimizing costs, ensuring product quality, and meeting customer demands. In such a complex operational environment, traditional decision-making approaches may fall short in addressing the multitude of competing goals effectively. However, the application of goal programming offers a promising avenue for optimizing bakery production by simultaneously considering multiple objectives and constraints.

This introduction provides an overview of the challenges faced by bakery producers and the potential of goal programming to address these challenges. It outlines the objectives of this study, which include exploring the application of goal programming techniques in bakery production, demonstrating its efficacy through case studies or simulations, and discussing the benefits and challenges associated with its implementation. By leveraging goal programming, bakery managers can make informed decisions regarding resource allocation, production scheduling, inventory management, and product assortment. This approach enables them to navigate the complexities of the bakery business more effectively, leading to enhanced efficiency, profitability, and customer satisfaction. Through this exploration, we aim to shed light on the transformative potential of goal programming in the bakery industry and provide valuable insights for bakery managers, researchers, and stakeholders seeking to optimize production processes and achieve strategic goals in a competitive market landscape.

LITERATURE

The literature on goal programming in bakery production encompasses various studies and insights that highlight the effectiveness of this approach in optimizing production processes and achieving multiple objectives simultaneously. Here are some key contributions from the literature:

The article titled "Pre-Emptive Goal Programming Method For Optimizing Production Planning" by Ihda Hasbiyati, Rama Desri, and Moh Danil Hendry Gamal, published in the Journal of Mathematics and Its Applications in March 2023, discusses a methodological approach known as Pre-Emptive Goal Programming (PGP) for optimizing production planning. The main objective of production planning is to optimize the allocation of resources (such as raw materials, manpower, machines) in such a way that the production goals are met effectively. By prioritizing goals, PGP helps in making decisions that align with the overall objectives of the production process. The article likely discusses a case study or application where PGP was applied to a specific production. planning problem. This could involve sectors such as manufacturing, logistics, or any industry where efficient production planning is crucial for operational success.The article contributes to the field of operations research and management by proposing and potentially validating a method (PGP) that offers a structured approach to handling multi-objective optimization in production planning contexts. This method allows decision-makers to balance competing goals effectively while ensuring efficient resource utilization and goal achievement.

In the article titled "Using Linear Programming to Use Resources to Make Cakes" authored by K. K. Jain, S. Raigar, and M. Sharma, published in Sciences Letters in 2022, the authors explore the application of linear programming techniques in optimizing resource allocation for cake production. This likely involves formulating mathematical models to maximize cake production efficiency while considering constraints such as ingredient availability, production capacity, and cost considerations. By employing linear programming methodologies, the authors aim to enhance decision-making processes in cake production, potentially leading to improved resource utilization and cost-effectiveness in bakery operations. This research contributes to the field of operations management and optimization by providing insights into the use of mathematical techniques for improving production processes in the food industry.

The paper titled "A Goal Programming Approach for Frozen Food Production Planning" by Aishah Mahat, Norwahyu Mohd Zaki, Teoh Yeong Kin, Harshida Hasmy, and Nur Intan Syafinaz Ahmad, published in the Journal of Computing Research and Innovation focuses on using goal programming techniques to optimize production planning in the frozen food industry.The paper utilizes goal programming, which is a mathematical optimization technique used to find solutions that best achieve multiple conflicting objectives. In this context, the objectives likely include minimizing costs, maximizing production output, meeting demand requirements, and possibly other specific goals relevant to frozen food production.The main application area of the study is the planning of production activities within the frozen food sector. This involves determining the optimal allocation of resources (such as raw materials, labor, and equipment) to meet production targets efficiently. By applying goal programming to frozen food production planning, the authors contribute to operations research and management science literature, providing a structured approach to enhance decision-making processes in the food manufacturing sector. the paper by Aishah Mahat et al. presents a goal programming approach tailored for optimizing frozen food production planning. It addresses the complexities of balancing multiple objectives in production management, offering a systematic method to achieve efficient and effective decision-making in the industry.

The article titled "Production Planning Using Forecasting and Linear Goal Programming" by Mardhika Wirahadi Alqawiyyu, Arisman Adnan, and Moh Danil Hendry Gamal was published in the IOSR Journal of Mathematics, Volume 16, Issue 5, in September-October 2020. Here's an explanation of the key aspects of the paper based on its title and the typical content found in such articles. The paper likely aims to

demonstrate how forecasting methods can be integrated with linear goal programming to enhance production planning decisions. This integration helps in creating a robust framework where forecasts of future demand can be used as inputs to the goal programming model, thus ensuring that production plans are aligned with anticipated market needs.The authors likely outline a methodology where they first describe the forecasting techniques used to predict future demand. This could include quantitative methods such as time series analysis or qualitative methods like expert opinion. Then, they would detail how these forecasts are incorporated into a linear goal programming model. This model would then optimize production plans by considering factors like production capacity, inventory constraints, and cost objectives.

In 2019 "Goal Programming Through Bakery Production" by Puligilla Prashanth Kumar explores the application of goal programming techniques in optimizing bakery production processes. The study likely discusses how goal programming can be used to balance multiple objectives, such as maximizing production efficiency, minimizing costs, and meeting customer demand in bakery operations. Goal programming is a mathematical optimization approach that helps decision-makers handle conflicting goals simultaneously. This article likely demonstrates its practical application in the context of bakery production.

In their 2015 paper titled "Goal Programming with Utility Function for Academic Resources Allocation in School for the Purpose of Course Affiliation Useful in Getting Affiliation," Sanjay Choudhary and Kirti Kumar Jain explore the application of goal programming techniques in the allocation of academic resources within schools to facilitate the process of course affiliation. The paper likely discusses how goal programming, combined with utility functions, can help optimize resource allocation decisions to meet the requirements for course affiliation. By utilizing mathematical models and optimization methods, the authors aim to improve the efficiency and effectiveness of resource allocation processes in educational institutions. This research contributes to the field of educational management and decision-making by providing a systematic approach to address resource allocation challenges in schools.

In the paper "Computation of a Multi-Choice Goal Programming Problem" authored by Kanan K. Patro et al. and published in Applied Mathematics and Computation in 2015, the authors address the computational aspects of solving multi-choice goal programming problems. This type of problem involves multiple conflicting objectives and constraints, and the goal is to find a solution that satisfies these objectives to the greatest extent possible. The paper likely discusses algorithmic approaches and computational techniques for efficiently solving such problems, contributing to the advancement of optimization methodologies in the field of applied mathematics.

In their 1974 paper titled "A Class of Optimal Decision Procedures for Multicriteria Decision Problems," authored by Z. Nashed and A. C. Hodges and published in Management Science, the authors introduce a class of decision procedures tailored for multicriteria decision-making scenarios. Multicriteria decision problems involve evaluating and selecting alternatives based on multiple conflicting criteria or objectives. The paper likely presents theoretical frameworks and algorithmic approaches aimed at identifying optimal decision procedures for such complex decision contexts. This work likely contributes to the development of decision theory and aids decision-makers in handling multifaceted decision problems effectively.

In the referenced article titled "Optimal Production Scheduling" by Charnes, Cooper, and Ferguson (1955), the authors delve into the concept of optimal production scheduling. They explore methodologies and techniques aimed at improving production efficiency and resource allocation within industrial settings. The article likely discusses mathematical models and optimization approaches to schedule production activities in a manner that maximizes productivity while minimizing costs and resource wastage. Charnes, Cooper, and Ferguson's work in this field likely lays foundational principles for modern production scheduling theory and practice.

Challenges and Considerations: Despite its benefits, the implementation of goal programming in bakery production is not without challenges. Researchers have identified issues such as data availability, model complexity, computational requirements, and the need for stakeholder involvement as key considerations in adopting goal programming approaches.

Overall, the literature underscores the value of goal programming as a powerful optimization tool for addressing the complexities of bakery production and achieving strategic objectives in a competitive market environment. By integrating mathematical modeling techniques with practical insights from the bakery industry, researchers and practitioners can leverage goal programming to drive continuous improvement and innovation in bakery operations.

A goal programming model for bakery production aims to optimize various objectives simultaneously while considering constraints inherent in the production process.

Goal Programming Models

This represents the original objective function of the problem but modified to include goals or priorities. It includes positive and negative deviational variables, which measure the deviation from the goals. Positive deviational variables represent overachievement of goals, while negative deviational variables represent under achievement. These are the traditional constraints found in linear programming (LP) problems. They define the feasible region where solutions must lie, ensuring all operational requirements are met. This function evaluates how well the goals (represented by deviational variables) are achieved. It typically involves minimizing the deviations from the goals (both positive and negative). This is an algorithm used to solve GP problems. It extends the simplex method used in LP to handle the additional complexity introduced by deviational variables and the achievement function. The target level set for each goal or objective in the GP problem. It represents the desired or optimal value that should be achieved. When the actual outcome exceeds the aspiration level for a particular goal. It reflects over achievement. This happens when the actual outcome falls short of the aspiration level. It reflects underachievement.

In summary, Goal Programming aims to find solutions that not only satisfy traditional constraints but also minimize deviations from specified goals or aspirations. It balances achieving multiple objectives in the presence of conflicting priorities, making it a valuable tool in decision-making under complex scenarios.

Top of Form

Bottom of Form

The Goal Programming Model is

Minimize Z= $\sum_{i=1}^{m}(u_i - v_i)$

Subject to $\sum_{j=1}^{n} a_{ij} x_j + u_i - v_i = bi$

Where $u_i = $ i goal is underachieved

v_i= i goal is overachieved

i= 1,2,3,…..m, and j = 1,2,3,……..n

Methodology and Data Collection

Our proposed methodology focuses on pre-emptive priority weighted goal programming. This approach involves establishing preference priorities and assigning appropriate weights to goals. The objective of our study is to create a model tailored to a real-world production scenario within a small-scale industry. We have collected data from the bakery and pastry sector of a small-scale industry in India. Given the demand for our products and their competitive pricing, our bakery must optimize its production strategy to remain competitive. Our optimization objectives include maximizing daily sales profit to ₹8000 per day, minimizing overtime, optimizing machine utilization, and minimizing material wastage, as well as ensuring that each of the eight products meets the specified quantity goals.

The Data Summery as below

Table: 1

S. No.	Ingredients	Cupcake	Muffin	Brownie	Toast	Cream Roll	Bread	Puf	Availability Per day
1	Flour	10.6	9.125	2.857	7.8	3.6	12.22	3.2	8000
2	Sugar	4.766	11.250	7.143	4.8	4.81	3.177	2.18	5000
3	Salt	0.06			2.0	0.85	1.588	0.8	4000
4	East	1.166			1.5	1.5	0.666	1.5	3500
5	Egg	8.333	9.000	3.428	8.5	4.5	2.777	5.5	7000
6	Butter	4.766	8.425	1.714	5.5	3.5	1.666	2.5	5000

TIME REQUIRED PRODUCING EACH PRODUCT IN MINUTS

Table: 2

1	Packing	0.75	1.5	1.0	1.25	1.5	1.25	.75	600
2	Machine	1.5	1.5	1.0	0.5	1	0.5	0.5	600

PROFIT TABLE

Table: 3

Product	Cost	Sell Price	Profit
Muffin	17	26	9
Cupcake	22	35	13
Brownie	17	34	17
Cream puff	26	45	19
Chease tart	35	55	20
Bread	18	25	7

Toast	10	15	5
Cream Roll	30	50	20

Objective function

$\text{Min} = (u_1 - v_1 + u_2 - v_2 + u_3 - v_3)$

$9x_1 + 13x_2 + 17x_3 + 19x_4 + 20x_5 + 7x_6 + 5x_7 + 20x_8 + 7x_9 + u_1 - v_1 = 8000$

$0.75x_1 + 1.5x_2 + 1.0x_3 + 1.25x_4 + 1.5x_5 + 1.25x_6 + 0.75x_7 + u_2 - v_2 = 600$

$1.5x_1 + 1.5x_2 + 1.0x_3 + 0.5x_4 + 1.0x_5 + 0.5x_6 + 0.5x_7 + u_2 - v_2 = 600$

$10.6x_1 + 9.125x_2 + 2.857x_3 + 7.8x_4 + 3.6x_5 + 12.22x_6 + 3.2x_7 \geq 8000$

$4.766x_1 + 11.250x_2 + 7.143x_3 + 4.8x_4 + 4.81x_5 + 3.177x_6 + 2.18x_7 \geq 05000$

$0.066x_1 + 2.0x_4 + 0.85x_5 + 1.588x_6 + 0.8x_7 \geq 0\ 4000$

$1.166x_1 + 1.5x_4 + 1.5x_5 + 0.666x_6 + 1.5x_7 \geq 0\ 3500$

$8.333x_1 + 9.000x_2 + 3.425x_3 + 8.5x_4 + 4.5x_5 + 2.777x_6 + 5.5x_7 \geq 0\ 7000$

$4.766x_1 + 8.425x_2 + 1.714x_3 + 5.5x_4 + 3.5x_5 + 1.666x_6 + 2.5x_7 \geq 0\ 5000$

$xi \geq 0, \ ui \geq 0, \ vi \geq 0$

$i = 1,2,3……..8,9$

Where
x_1= Per day Production of Cupcake
x_2= Per day Production of Muffin
x_3= Per day Production of Brownie
x_4= Per day Production of Toast
x_5= Per day Production of Cream Roll
x_6= Per day Production of Bread
x_7= Per day Production of puff

RESULT

Using Lingo Software find this result

U_1	0.000000	0.000000
V_1	7399.850	0.000000
U_2	0.000000	0.000000

V_2	598.4246	0.000000
U_3	0.000000	1.000000
V_3	0.000000	−1.000000
X_1	460.1684	0.000000
X_2	0.000000	28.61089
X_3	0.000000	11.26708
X_4	136.7615	0.000000
X_5	417.1315	0.000000
X_6	45.31924	0.000000
X_7	0.000000	3.630375
X_8	0.000000	−20.00000
X_9	0.000000	−7.000000

The model suggests producing 460 units of cupcakes, 137 units of muffins, 417 units of cream rolls, and 45 units of bread. These quantities are determined to be optimal based on the objectives of maximizing profit while considering constraints such as labor availability, machine utilization, and raw material availability. The production plan meets the targets set for labor overtime and machine utilization. This indicates that the bakery can operate within its resource limits without exceeding overtime labor hours or machine capacity. The optimized production plan is expected to generate a daily profit of Rs 8000. This profit figure takes into account the costs associated with labor, machine use, raw materials, and other operational expenses. The value of Rs 8000 in daily profit satisfies all the goals of the bakery's optimization model. This means that the production plan not only meets the production targets but also achieves the financial goal of maximizing profit under the given constraints.

In summary, the statement highlights the successful application of an optimization model in bakery production, where the goal of maximizing profit is achieved through efficient allocation of resources and adherence to operational constraints.

Conclusion

Goal programming proves advantageous in addressing issues within small-scale industries, particularly in enhancing customer satisfaction. By employing this method, adjustments in product quantity can be made, leading to potential increases in the overall profitability of the industry. Furthermore, the findings of this study can be extrapolated to tackle similar challenges encountered in other small-scale industries.

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