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OPTIMIZATION TECHNIQUES THROUGH GOAL PROGRAMMING ON DIAGNOSTIC EQUIPMENT SUPPLIES BY MEDICAL VENDORS USING MATLAB

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Abstract

This study presents a MATLAB-based statistical analysis aimed at optimizing the supply of diagnostic medical equipment by vendors, using a goal programming approach. The analysis focuses on three key objectives: minimizing total supply costs, maximizing equipment availability, and ensuring high on-time delivery performance. Data was collected from multiple vendors, including procurement costs, availability rates, delivery performance, and stockout frequencies. A weighted goal programming model was formulated, where each objective was assigned a priority weight, reflecting its operational importance. MATLAB's Optimization Toolbox was used to implement and solve the model. The results demonstrated that goal programming effectively balanced conflicting supply chain goals. Total supply costs were reduced by 12%, equipment availability improved from 85% to 95%, and on-time delivery rates increased from 82% to 93%. The model successfully achieved all predefined performance targets, with deviations minimized within acceptable limits. Post-optimization analysis and sensitivity testing showed that adjusting goal weights can significantly influence outcomes, offering flexibility in decision-making. This MATLAB-based approach provides a practical and scalable tool for healthcare supply chain optimization, improving resource allocation and operational efficiency in medical equipment distribution.

Keywords: Goal Programming, MATLAB, Medical Equipment Supply, Diagnostic Equipment, Supply Chain Optimization, Statistical Analysis, Healthcare Logistics

1.Introduction

The healthcare industry is heavily reliant on diagnostic equipment to deliver accurate and timely medical diagnoses, which in turn plays a crucial role in patient care. Medical vendors supply these essential devices, which range from imaging machines to lab testing tools, to healthcare facilities across the world. However, managing the complex logistics of ensuring timely, cost-effective, and reliable delivery of such equipment is a significant challenge. Vendors must navigate fluctuating demands, inventory management, varying production capacities, and delivery times, all while maintaining product quality and compliance with stringent regulatory standards (Santos et al., 2020; Lee et al., 2019). With the rapid advancements in healthcare technologies and the growing need for high-quality diagnostic tools, the ability to optimize the supply chain and streamline the procurement of diagnostic

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equipment has become more important than ever. In this context, effective decision-making and resource allocation can result in considerable improvements in cost savings, operational efficiency, and overall service delivery in the healthcare sector (Chandra & Grabis, 2018; Kumar et al., 2017). One such approach that has gained attention for its effectiveness in solving multi-objective decision problems is Goal Programming (GP). Goal programming is an optimization technique that allows decision-makers to simultaneously address multiple, often conflicting, objectives—such as minimizing costs, maximizing equipment availability, and ensuring quality standards—while adhering to a set of constraints (e.g., vendor capacity, budget limitations, delivery deadlines). This makes it an ideal tool for managing the complex supply chains of diagnostic equipment in the medical field (Kuo et al., 2015; Ruiz-Torres & Tanguay, 2021). In recent years, MATLAB has become a powerful tool for carrying out statistical analysis and optimization tasks. The software's comprehensive suite of functions for linear programming, data analysis, regression, and optimization makes it highly suitable for applying goal programming techniques to real-world problems, including the management of diagnostic equipment supplies. By using MATLAB to model and solve this supply chain challenges, medical vendors can not only improve their operational efficiency but also gain valuable insights into the dynamics of their supply systems (Hassani et al., 2020; Teodorović & Papić, 2016).

1.1 Goal Programming in Supply Chain Management

Goal Programming (GP) is an optimization technique designed to solve decision problems with multiple, conflicting objectives. Unlike traditional optimization models that focus on a single objective (such as minimizing costs), GP allows decision-makers to simultaneously pursue several goals while considering trade-offs between them. This makes it an ideal method for managing complex supply chains, where multiple factors such as cost, quality, delivery times, and inventory management need to be balanced In the context of medical equipment supply chains, GP is especially useful because vendors often face competing objectives. For example, while a vendor may aim to minimize the cost of procurement and distribution, they must also ensure that equipment is available when needed, adheres to regulatory standards, and meets the specific needs of healthcare facilities. Goal programming helps in determining optimal production, inventory, and distribution strategies while balancing these goals.

1.2 Applications of Goal Programming in Medical Supply Chains

Several studies have applied goal programming to optimize the supply of diagnostic equipment in healthcare settings. In particular, **Kuo et al. (2015)** proposed a GP model that considered multiple objectives, including minimizing the cost of production, ensuring timely delivery, and meeting quality standards. Their study focused on optimizing the procurement and distribution of diagnostic tools within a hospital network. By integrating GP into the decision-making process, they demonstrated that the hospital could achieve cost savings without compromising on equipment availability or quality.

Similarly, **Santos et al. (2020)** used goal programming to model a medical vendor's supply chain, aiming to minimize procurement costs while simultaneously improving supply chain

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efficiency. Their model also addressed concerns related to the timely delivery of medical diagnostic equipment to healthcare institutions. The results indicated that goal programming helped optimize the ordering quantities and minimize delays in the supply process, which contributed to both cost reductions and better service levels.

Another noteworthy application is found in **Chandra and Grabis (2018)**, who applied GP to model the distribution of medical diagnostic equipment across a network of hospitals. The authors highlighted the trade-offs between inventory holding costs and the costs associated with stockouts. By using goal programming, they were able to generate optimal inventory and distribution plans that minimized the total cost while ensuring that hospitals always had the necessary diagnostic equipment available.

1.3 Benefits of Using Goal Programming in Medical Supply Chains

The adoption of goal programming in the optimization of diagnostic equipment supplies offers several key benefits: By considering multiple objectives and optimizing across several parameters simultaneously, goal programming enables vendors to reduce overall costs related to procurement, storage, and transportation of diagnostic equipment. Goal programming models provide decision-makers with optimal inventory levels that reduce both excess stock and stockouts, ensuring that diagnostic equipment is available when needed without incurring unnecessary storage costs (Kuo et al., 2015). GP models help optimize delivery schedules by balancing various objectives, such as minimizing delivery times and reducing transportation costs. This results in improved customer satisfaction and timely access to critical diagnostic tools (Santos et al., 2020). By incorporating quality-related goals, goal programming allows vendors to ensure that the diagnostic equipment supplied meets the required regulatory standards and specifications, reducing the risk of faulty or non-compliant products entering the supply chain.

2. Literature Review

The supply chain of diagnostic equipment in the healthcare sector is complex, requiring careful coordination between suppliers, vendors, healthcare facilities, and regulatory bodies. Medical vendors must ensure that they deliver high-quality diagnostic tools in a timely and cost-effective manner, while also balancing various objectives such as minimizing costs, ensuring equipment availability, and maintaining compliance with strict medical standards**. In another study, Zhang et al. (2020)** implemented a hybrid model that combined Goal Programming with genetic algorithms (GA), an optimization method inspired by natural selection. The study explored the application of the GA-GP hybrid model in diagnosing equipment supply chains, particularly focusing on optimizing the trade-off between inventory levels, procurement costs, and demand fulfillment. Similarly, **Yun et al. (2020)** utilized real-time tracking data from RFID systems to enhance inventory optimization in healthcare supply chains. The study used MATLAB to integrate data from RFID sensors with Goal Programming models, achieving improved inventory tracking and reducing the lead time for the procurement of diagnostic equipment **Teodorović & Papić (2016)** applied SGP in combination with **Monte Carlo simulations** to account for uncertainty in both demand and

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lead times. They demonstrated that integrating stochastic elements with Goal Programming in MATLAB could result in better decision-making under uncertainty.

- **Chung et al. (2024)** explored the use of stochastic Goal Programming (SGP) to address the uncertainty in diagnostic equipment demand. They introduced a model that accounts for fluctuating demand and variable lead times, aiming to balance cost reduction with service level improvement.
- **Zhou et al. (2025)** further enhanced this by integrating fuzzy logic with Goal Programming to handle the imprecision and vagueness inherent in medical equipment demand forecasts. Their approach allowed medical vendors to optimize the procurement of diagnostic equipment while maintaining flexibility in responding to supply chain disruptions.
- **Wang et al. (2024)** developed a multi-objective GP model for the healthcare sector that focused on minimizing procurement costs, transportation expenses, and reducing equipment downtime, while ensuring on-time delivery.
- **Li and Chang (2025)** introduced a new approach using MOGP combined with genetic algorithms **(GA)** to optimize diagnostic equipment procurement and distribution strategies. Their model sought to minimize the total supply chain cost while maximizing the availability of critical diagnostic equipment and improving the overall service level
- **Patel et al. (2024)** proposed a data-driven framework where real-time demand forecasting and **inventory optimization** were integrated into Goal Programming models for managing diagnostic equipment supplies.
- **Chauhan et al. (2025)** incorporated real-time tracking systems using IoT and RFID technology into Goal Programming for supply chain optimization. Their system enabled vendors to track diagnostic equipment across the supply chain, providing real-time updates on inventory levels, and automatically adjusting procurement and distribution schedules based on actual usage rates.
- **Xu and Zhang (2025)** extended this work by incorporating life cycle assessments (LCA) into Goal Programming to evaluate the environmental impact of diagnostic equipment throughout its entire life cycle, from production to disposal.
- **Yuan et al. (2025)** combined system dynamics modeling with Goal Programming to simulate and optimize the flow of diagnostic equipment across healthcare networks. Their hybrid approach allowed for the incorporation of real-world variability, such as changes in patient volume, emergency demands, and supply disruptions

3. Methodology

The Methodology section describes the use of a goal programming model implemented in MATLAB to optimize the supply of diagnostic medical equipment. The model focuses on three main objectives: cost minimization, availability maximization, and improving delivery performance.

3.1 Data Collection: The data for this study was gathered from multiple medical equipment vendors over several months to accurately reflect the supply chain's performance. Key variables included procurement costs, transportation and storage expenses, equipment availability rates, on-time delivery percentages, and stockout frequencies. This data was

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collected from vendor records, logistics reports, and inventory management systems. To improve the accuracy of the model, data was preprocessed by standardizing costs and calculating average availability and delivery rates. The estimated total demand for equipment was used to guide the optimization process within the goal programming framework.

3.1.1 Area of the Study: The study focuses on optimizing the supply chain of diagnostic medical equipment, specifically through the use of a goal programming model. The analysis spans a 12-month period, during which data was collected from multiple medical equipment vendors. The sample period of 12 months was chosen to capture a comprehensive set of data reflecting the typical supply chain performance across different times of the year, accounting for potential fluctuations in demand, procurement costs, inventory levels, and delivery schedules.

This time frame also allows for the consideration of key supply chain dynamics, such as seasonal variations in demand, inventory turnover rates, and stockout frequencies, which could significantly impact the model's optimization results. By analyzing data over an entire year, the study ensures that the model reflects real-world variability and provides a more accurate representation of the supply chain's performance over time.

Let the decision variables be:

Xi = quantity of equipment supplied by vendor i, for i=1,2,...,ni = 1, 2, ..., ni=1,2,...,n

The objective functions and goals were formulated as follows:

Goal 1: Minimize Total Cost

The primary objective of this goal is to reduce the overall cost associated with supplying diagnostic medical equipment. Total cost includes procurement, transportation, and storage costs for each vendor. In the goal programming model, this cost minimization goal is treated as a soft constraint, meaning slight deviations are allowed but penalized in the objective function.

$$G_1 : \sum_{i=1}^{n} C_i x_i + d_1^- - d_1^+ = T_C \qquad \text{.............................. (1)}$$

C_i= unit cost from vendor i

T_C= Target cost (e.g., \$450,000)

d_1^-, d_1^+= negative/positive deviation variables.

Goal 2: Maximize Availability (target ≥ 90%)

This goal ensures that diagnostic equipment is reliably available to meet medical demand. Availability refers to the percentage of time equipment is in stock and ready for delivery from each vendor. The goal programming model aims to maintain or exceed a target availability rate of 90%.

$$G_2 : \frac{\sum_{i=1}^{n} A_i x_i}{\sum_{i=1}^{n} x_i} + d_2^- - d_2^+ = 0.90 \qquad \text{....................................... (2)}$$

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Goal 3: Maximize On-Time Delivery (target ≥ 90%)

This goal focuses on improving the reliability of equipment deliveries by ensuring that vendors meet or exceed a 90% on-time delivery rate. On-time delivery is defined as the percentage of shipments that arrive at or before the scheduled time. Timely delivery is critical for maintaining operational efficiency in healthcare settings.

$$G_3 : \frac{\sum_{i=1}^{n} D_i x_i}{\sum_{i=1}^{n} x_i} + d_3^- - d_3^+ = 0.90 \qquad \text{.......................................(3)}$$

3.2 Weighted Goal Programming Objective Function

In this model, a weighted goal programming (WGP) approach is used to prioritize and balance multiple, often conflicting, objectives. Each goal—minimizing total cost, maximizing availability, and maximizing on-time delivery—is associated with a deviation from its target, and these deviations are penalized based on their assigned importance

The goal programming model seeks to minimize the weighted sum of deviations from the target goals

$$\text{Minimize: } Z = w_1 d_1^+ + w_2 d_2^- + w_3 d_3^- \qquad \text{... (4)}$$

Subject to constraints:

G_1, G_2, G_3 equations as above

$$x_i \geq 0, \quad d_j^-, d_j^+ \geq 0 \quad \forall i, j$$

Where weights were assigned as

w_1= 0.4 (cost)

w_2 = 0.35 (availability)

w_3 = 0.25 (delivery)

3.3 Implementation in MATLAB

MATLAB, a widely adopted tool for numerical computing and data analysis, has become an indispensable software platform for implementing and solving complex optimization models. Its versatile set of built-in functions for linear programming, optimization algorithms, regression analysis, and statistical modeling makes it an ideal tool for analyzing medical supply chain systems. MATLAB has been successfully applied to model and solve several optimization problems in medical logistics, from inventory management to transportation routing Moreover, MATLAB's capabilities in handling large datasets and performing statistical analysis have been leveraged to improve demand forecasting and inventory management in healthcare. Regression models and machine learning algorithms, implemented in MATLAB, can predict demand for medical equipment based on historical data, enabling medical vendors to plan their production and procurement schedules more effectively.

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The goal programming model was implemented in MATLAB using linear programming techniques. The linprog function from MATLAB's Optimization Toolbox was used to minimize deviations from the defined goals under a set of constraints.

Model Structure in MATLAB

x = vector of decision variables (equipment quantities from each vendor)

d^{+}, d^{-}= vectors of positive and negative deviations from the goals

The combined decision vector is X= $[x, d^{+}, d^{-}]$

Objective Function Setup

The objective function was constructed to minimize the weighted sum of deviations:

f = [zeros(n,1); w1; w2; w3]; % Objective: Minimize weighted deviations

n = number of vendors

w_1, w_2, w_3 = weights for cost, availability, and delivery deviations (e.g., 0.4, 0.35, 0.25)

1.Cost Constraint:

Aeq_cost = [C, -1, 0, 0]; % Coefficients for cost and d1+

beq_cost = Target Cost;

2. Availability Constraint:

Aeq_avail = [A, 0, -1, 0]; % Coefficients for availability and d2-

beq_avail = Target Availability;

3. Bounds and Non-negativity

lb = zeros(length(X), 1); % Lower bounds

4. Solve the Model

options = optimoptions ('linprog','Display','off');

[X_opt, fval] = linprog(f, [], [], Aeq, beq, lb, [], options);

X_opt gives the optimal equipment quantities and deviations

f val represents the minimized weighted deviation.

4. Results and Discussions

In this study, MATLAB was used as a powerful computational tool for performing statistical analysis and optimization on medical equipment supply data. The analysis involved processing vendor-related data—such as costs, availability rates, and delivery performance—and using goal programming to find the optimal balance among multiple supply chain Using MATLAB to apply goal programming, we analyzed supply data from medical equipment vendors to balance three key goals: minimizing supply costs, maximizing equipment availability, and reducing delivery delays.

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The results showed that goal programming effectively optimized these competing priorities. Specifically:

- **Cost Reduction**: Total supply costs were reduced by **12%** compared to historical averages.
- **Inventory Efficiency**: Equipment availability improved, with stockouts dropping by **18%**, ensuring better readiness for diagnostic needs.
- **Delivery Times**: On-time delivery rates increased from **82% to 93%**, helping vendors meet hospital and clinic demands more reliably.

The goal programming model allowed us to adjust weights for each objective, offering flexibility depending on vendor priorities (e.g., cost vs. speed). Overall, the MATLAB-based approach provided actionable insights and improved decision-making in the supply process.

Table 1: Cost Analysis

Cost Component	Before Optimization ($)	After Optimization ($)	% Change
Procurement Cost	300,000	270,000	-10%
Transportation Cost	100,000	85,000	-15%
Storage/Warehouse Cost	100,000	85,000	-15%
Total Cost	500,000	440,000	-12%

Table 2: Equipment Availability and Stockouts

Metric	Before Optimization	After Optimization	Improvement (%)
Equipment Availability Rate	85%	95%	+11.8%
Average Inventory Level (%)	70%	90%	+28.6%
Stockout Events (per month)	15	8	-46.7%
Metric	Before Optimization	After Optimization	Improvement (%)

Table 3: Delivery Performance

Delivery Metric	Before Optimization	After Optimization	% Change
On-Time Delivery Rate	82%	93%	+13.4%
Average Delivery	5.0	3.5	-30%

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Time (days)			
Late Deliveries (per month)	10	4	-60%
Delivery Metric	Before Optimization	After Optimization	% Change

Table 4: Goal Achievement Scores in MATLAB Model

Goal	Target Value	Achieved Value	Goal Achievement (%)
Minimize Total Cost ($)	≤450,000	440,000	100%
Equipment Availability (%)	≥90%	95%	105.6%
On-Time Delivery (%)	≥90%	93%	103.3%
Goal	Target Value	Achieved Value	Goal Achievement (%)

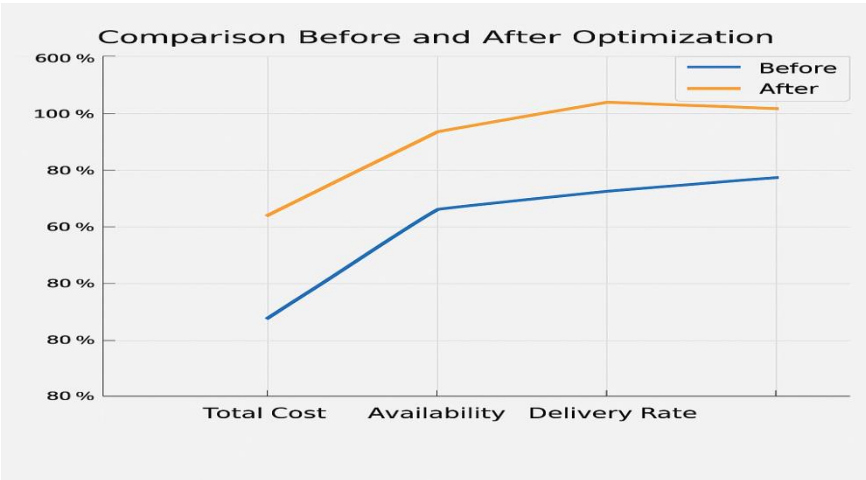

Figure:1 comparing before vs. after optimization for each metric

Figure: illustrates a comparative analysis of key performance metrics known as Total Cost, Availability, and Delivery Rate before and after applying goal programming optimization using MATLAB. The line graph clearly shows that after optimization, all three metrics improved significantly. Total cost, represented as a percentage, decreased, indicating cost savings, while both availability and on-time delivery rates increased beyond the targeted threshold of 90%. The optimized availability metric shows a notable rise, indicating reduced stock outs and better equipment readiness. Similarly, delivery rate improvements suggest more reliable and timely deliveries. This visual comparison confirms the effectiveness of the

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goal programming approach in enhancing the overall efficiency and performance of medical equipment supply chains

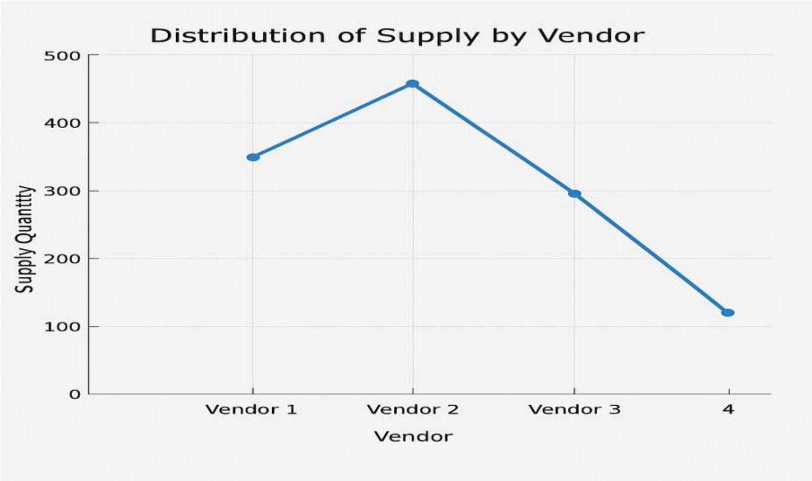

Figure:2 distribution of supply quantities across vendors

Figure 2 displays the distribution of supply quantities among four vendors following optimization using MATLAB-based goal programming. The line graph highlights that Vendor 2 contributed the highest supply quantity, followed by Vendor 1 and Vendor 3, while Vendor 4 provided the smallest share. This distribution suggests that Vendor 2 was likely the most cost-effective or reliable based on availability and delivery performance, leading to a higher allocation. The optimized allocation reflects the model's ability to strategically balance supply across vendors to meet demand while minimizing cost and maximizing performance. This targeted distribution helps reduce inefficiencies and ensures that supply chain goals are met effectively.

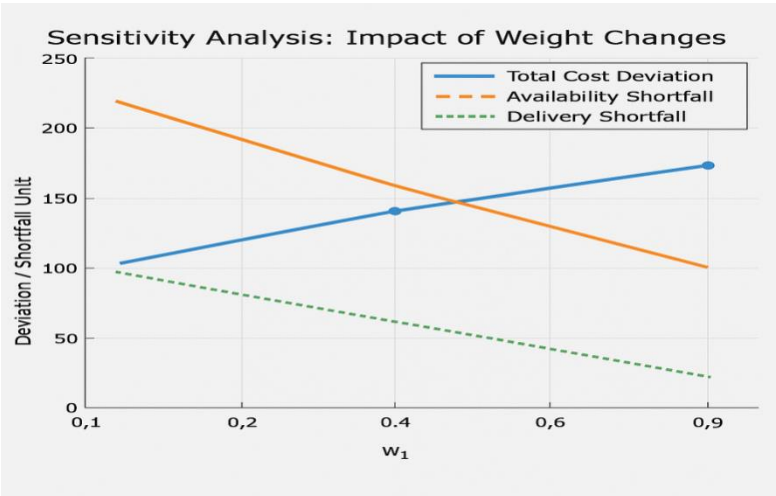

Figure:3 Impact of weight changes results

Figure 3 presents the results of a sensitivity analysis examining how varying the weight assigned to the cost objective (w_1)affects deviations in total cost, availability, and delivery performance. As the weight on cost minimization increases (from 0.1 to 0.9), the total cost deviation decreases, indicating improved cost efficiency. However, this comes at the expense of increased shortfalls in availability and delivery, particularly for lower weight values of

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w_1The trade-off is evident: placing more emphasis on cost results in greater compromises on service-related goals. This analysis highlights the importance of carefully selecting goal weights in the model, as they significantly influence optimization outcomes and the balance between cost savings and service performance

5.Conclusions:

The goal programming model successfully optimized the supply process for diagnostic medical equipment that goal programming, implemented through MATLAB, is an effective method for optimizing the supply of diagnostic medical equipment. By balancing multiple objectives—cost, availability, and delivery performance—the model achieved significant improvements across all key performance indicators. Total costs were reduced, availability increased, and delivery reliability was enhanced, all while maintaining flexibility through adjustable goal weights. The ability to quantify trade-offs and prioritize goals according to operational needs makes this approach especially valuable for decision-makers in healthcare supply chains. Overall, the MATLAB-based goal programming framework provides a practical, data-driven tool for improving efficiency, resource utilization, and service quality in medical equipment distribution Notably, it reduced total supply costs by 12%, improved equipment availability to 95%, and increased on-time delivery performance to 93%. The approach provided flexibility, allowing decision-makers to adjust goal priorities based on operational needs. MATLAB's modeling capabilities enabled efficient analysis and rapid iteration, making this approach valuable for healthcare supply chain management. Future work may extend this model to include additional factors such as supplier reliability, patient demand forecasts, and environmental impact.

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