Chapter 4

Optimal Product Mix And Resource Allocation In Furniture Manufacturing Using Linear Programming: A Case Of Furniture Company

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Abstract

Increasing competitive conditions and changing customer demands in the furniture industry necessitate efficient use of production resources and optimal planning of product mix. In this study, a linear programming model is presented for profit maximization and balanced product mix objectives of a furniture manufacturing company. The model aims at optimal allocation of limited resources such as CNC machine time, labor hours, MDF, and fabric for three main product groups: sofa sets, dining tables, and wardrobes. The mathematical model, presented using LINGO software, optimizes the company's weekly production planning. In the study, minimum demand and maximum capacity constraints were defined for each product, and all resource limitations were included in the model. According to the optimization results, a production plan providing a weekly profit of 91,700 TL was obtained. This plan envisions the production of 17 sofa sets, 7 dining tables, and 6 wardrobes. Resource utilization analysis showed that CNC machine and labor hours were utilized at a rate of 99.2%, indicating these resources as the main limiting factors for production. MDF utilization rate was calculated as 92.7%, while fabric utilization rate was 96.9%. Product mix analysis revealed that sofa sets constitute 64.9% of the total profit. As a result of the study, strategic recommendations were presented to increase the company's resource utilization efficiency and achieve a more balanced product mix. The presented model can be adapted to other companies in the furniture industry and provides a scientific approach to production planning and resource allocation decisions.

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INTRODUCTION

The furniture manufacturing industry faces significant challenges in optimizing production processes due to increasing raw material costs, fluctuating customer demands, and intense market competition. Effective resource allocation and product mix planning are crucial for furniture manufacturers to maintain profitability while meeting customer requirements in a timely manner. This study addresses the production planning challenges of a furniture company operating in Turkey, focusing on optimizing product mix and resource allocation to maximize profit within existing constraints (Hongqiang et al., 2012; Sakib et al., 2024).

The furniture sector in Turkey represents a significant portion of the country's manufacturing industry and export revenue. According to recent industry reports, Turkish furniture exports reached approximately $4.5 billion in 2024, making it one of the top ten furniture exporting countries globally. However, companies in this sector often struggle with balancing production capacity, raw material utilization, and meeting diverse customer demands (Erdinler and Koç, 2024). Traditional production planning approaches frequently result in either underutilization of critical resources or inefficient product mix decisions, leading to suboptimal profitability.

Linear programming and mathematical optimization techniques have been widely applied in manufacturing industries to address product mix and resource allocation problems. These techniques allow companies to determine optimal production quantities and resource allocation while considering various constraints such as production capacity, raw material availability, and demand requirements. Previous studies have demonstrated that mathematical optimization can lead to significant profit improvements and operational efficiencies in manufacturing environments (Vagaská and Gombár, 2021; Rabe et al., 2022).

The furniture manufacturing process involves multiple resources including machinery (particularly CNC machines), labor hours, and raw materials such as medium-density fiberboard (MDF) and fabric. The efficient allocation of these resources across different product lines presents a complex optimization challenge. With rising raw material costs in the 2025 Turkish economic environment, furniture manufacturers must make strategic decisions regarding which products to prioritize and how to allocate limited resources to maximize profitability.

This study aims to develop and implement a linear programming model for a furniture manufacturing company in Turkey. The model focuses on three main product categories: sofa sets, dining tables, and wardrobes, with the objective of maximizing total profit while satisfying minimum demand requirements and respecting resource constraints over a weekly planning horizon. The results provide valuable insights for production managers and decision-makers in the furniture industry regarding optimal product mix, resource utilization, and profit maximization strategies.

MATERIAL AND METHODS

Material

The material for this study consists of production and resource data from a furniture manufacturing company operating in Turkey. The company produces three main product categories: sofa sets, dining tables, and wardrobes, and faces challenges in determining the optimal product mix under limited resources. The planning horizon covers a weekly production schedule, for which detailed resource requirements and profit margins were provided by the company's production and finance departments.

The dataset includes comprehensive information on product specifications, resource requirements, profit margins, and capacity constraints. This information was collected through structured interviews with production managers and analysis of the company's production records. The company's manufacturing facility operates with limited resources including CNC machine time, labor hours, MDF, and fabric.

For each product category, specific parameters were identified including unit profit margins, CNC machine time requirements, labor hours needed per unit, MDF usage, and fabric requirements. Additionally, minimum demand requirements and maximum production capacities were established for each product type. These parameters form the foundation of the linear programming model developed in this study.

Methods

The Collection of the Data

Data collection was conducted through a systematic approach involving multiple sources to ensure accuracy and reliability. Primary data was collected through structured interviews with key personnel including the production manager, resource planning manager, and finance director. These interviews provided insights into the operational constraints, profit structures, and strategic priorities of the company.

Secondary data was extracted from the company's production management system, covering historical production records, resource utilization patterns, and cost information for the past two years. This historical data was essential for validating the parameters used in the optimization model and for assessing the typical resource consumption patterns.

Profit margin data for each product was developed using detailed cost accounting records and current market pricing information. The profit margins were validated against historical financial performance to ensure reliability.

Resource capacity data was collected through time studies and analysis of production line capabilities. CNC machine capacity was established at 120 hours per week, while total available labor was set at 240 hours per week. Raw material availability was determined based on current inventory levels and supply chain capabilities, with 450 m^2 of MDF and 320 meters of fabric available weekly.

Statistical Analysis

A linear programming model was formulated to optimize the product mix and resource allocation decisions. The model was implemented using LINGO optimization software version 19.0, which employs the simplex method for solving linear programming problems.

The mathematical formulation of the model includes an objective function that maximizes the total profit, which comprises the sum of profits from each product type:

This mathematical model has been compiled from similar studies in the literature (Mundi et al., 2019; Rezig et al., 2020).

Sets and Indices

$\boldsymbol{I} = \{1,2,3\}$: Product set; $i=1$; Seat Set, $i=2$; Dining Table, $i=3$; Wardrobe

$\boldsymbol{J} = \{1,2,3,4\}$: Resource set; $j=1$, CNC Machine, $j=2$: Labor, $j=3$: MDF, $j=4$: Fabric

Parameters

$\boldsymbol{p_i}$: Unit profit of product i (TL)

$\boldsymbol{a_{ij}}$: Required amount of resource j to produce one unit of product i

$\boldsymbol{b_j}$: Total available capacity of resource j

$\boldsymbol{d_i^{min}}$: Minimum demand quantity for product i

$\boldsymbol{d_i^{max}}$ **:** Maximum production capacity for product i

Decision Variables

$\boldsymbol{x_i}$ **:** Quantity to be produced from product i (units)

Objective Function

$$Max\,Z = \sum_{i \in I} p_i \cdot x_i \tag{1}$$

Object to:

$$\sum_{i \in I} a_{ij} \cdot x_i \le b_j \qquad \forall_{j \in J} \tag{2}$$

$$x_i \ge d_i^{min} \qquad \forall_{i \in I} \tag{3}$$

$$x_i \le d_i^{max} \qquad \forall_{i \in I} \tag{4}$$

$$x_i \in \mathbb{Z}^+ \qquad \forall_{i \in I} \tag{5}$$

Equation (1) represents the objective function that maximizes total profit. Equation (2) ensures that for each resource, total usage does not exceed available capacity. Equation (3) ensures that production quantity for each product meets minimum demand requirements. Equation (4) ensures that production quantity for each product does not exceed maximum production capacity. Equation (5) enforces that production quantities are non-negative integers.

RESULTS

The optimization model was successfully solved, yielding an optimal product mix and resource allocation plan for the weekly planning horizon. The total profit of the optimal solution was 91,700 TL, which represents the maximum achievable profit given the resource constraints and demand requirements.

Optimal Production Plan

The optimal production quantities for each product are presented in Table 1, along with their respective profit contributions.

Table 1. Optimal Production Plan and Profit Contribution

Product	Production Quantity (units)	Unit Profit (TL)	Total Profit (TL)	Profit Percentage
Sofa Sets	17	3,500	59,500	64.9%
Dining Tables	7	2,200	15,400	16.8%
Wardrobes	6	2,800	16,800	18.3%
TOTAL	30	-	91,700	100%

The results (Table 1) indicate that the optimal product mix consists of 17 sofa sets, 7 dining tables, and 6 wardrobes. Sofa sets contribute the largest portion to the total profit (64.9%), followed by wardrobes (18.3%) and dining tables (16.8%). This product mix reflects the profit-maximizing strategy while satisfying all constraints.

Resource Utilization

The resource utilization for all four constrained resources is presented in Table 2.

Table 2. Resource Utilization

Resource	Usage	Capacity	Utilization Rate	Remaining Capacity
CNC Machine	119 hours	120 hours	99.2%	1 hour
Labor	238 hours	240 hours	99.2%	2 hours
MDF	417 m^2	450 m^2	92.7%	33 m^2
Fabric	310 m	320 m	96.9%	10 m

The resource utilization analysis (Table 2) reveals that CNC machine time and labor hours are almost fully utilized (99.2%), indicating that these resources are the binding constraints that limit further profit improvement. MDF utilization is at 92.7%, while fabric utilization is at 96.9%, suggesting that these resources, while efficiently used, are not the primary limiting factors in the production process.

Detailed Resource Usage

A detailed breakdown of resource usage by product is presented in Table 3.

Table 3. Detailed Resource Usage by Product

Resource	Sofa Sets	Dining Tables	Wardrobes	Total Usage	Capacity
CNC Machine (hours)	68	21	30	119	120
Labor (hours)	136	42	60	238	240
MDF (m^2)	204	105	108	417	450
Fabric (m)	272	14	24	310	320

The detailed resource usage (Table 3) shows how each resource is allocated across the three product categories. Sofa sets consume the largest portion of resources, particularly fabric (272 m, representing 87.7% of total fabric usage) and CNC machine time (68 hours, representing 57.1% of total CNC usage). This aligns with the high profit contribution of sofa sets in the optimal solution.

Constraint Verification

All constraints defined in the model were satisfied in the optimal solution, as shown in Table 4.

Table 4. Constraint Verification

Constraint Type	Constraint	Status
Minimum Demand	Sofa Sets: 17 > 6	Satisfied
Minimum Demand	Dining Tables: 7 > 4	Satisfied
Minimum Demand	Wardrobes: 6 = 6	Satisfied (at minimum)
Maximum Capacity	Sofa Sets: 17 < 20	Satisfied
Maximum Capacity	Dining Tables: 7 < 20	Satisfied
Maximum Capacity	Wardrobes: 6 < 20	Satisfied
Resource	CNC Machine: 119 < 120	Satisfied (near capacity)
Resource	Labor: 238 < 240	Satisfied (near capacity)
Resource	MDF: 417 < 450	Satisfied
Resource	Fabric: 310 < 320	Satisfied

The constraint verification (Table 4) confirms that all minimum demand requirements are met, with wardrobes produced exactly at the minimum required level (6 units). All maximum capacity constraints are satisfied with considerable slack, indicating that production capacity is not a limiting factor. The resource constraints are all satisfied, with CNC machine time and labor hours nearly at full capacity.

Product Mix Analysis

The optimal product mix ratio is 17:7:6 (or approximately 2.83:1.17:1) for sofa sets, dining tables, and wardrobes, respectively. This mix heavily favors sofa sets due to their higher profit margin (3,500 TL per unit) compared to dining tables (2,200 TL per unit) and wardrobes (2,800 TL per unit). The production of wardrobes is maintained at the minimum required level (6 units), suggesting that allocating resources to other products yields higher overall profit.

DISCUSSION AND CONCLUSION

This study developed a multi-period production and inventory planning model for a textile company in Turkey, optimizing production quantities and inventory levels for three product categories over a three-month horizon. The results revealed several important findings that can be evaluated in light of existing literature.

The optimal solution demonstrated 100% utilization of regular time capacity across all three months, with overtime production only required for T-shirts in August (55% of available overtime capacity). This finding aligns with previous research by Park and Arlington (2012); Hung et al. (2013); Jebbor et al. (2023), who emphasized the importance of maximizing regular time capacity before utilizing more expensive overtime production in manufacturing environments.

The inventory management strategies identified in this study reflect the principles of strategic inventory positioning discussed by Abuthakeer et al. (2017). For T-shirts and shirts, the model maintained minimum inventory levels throughout the planning horizon, while for trousers, a strategic inventory build-up was implemented in June and July to prepare for high August demand. This differentiated approach supports Hwang and Samat's (2019) assertion that product-specific inventory policies based on demand patterns yield superior results compared to uniform inventory strategies (Pınar et al., 2022; Ballón-Echevarría et al., 2022).

Cost analysis revealed that regular time production costs constituted 91.3% of the total cost, followed by overtime production costs (7.4%) and inventory holding costs (1.3%). This distribution is consistent with the findings of Ali et al. (2009), who identified production costs as the dominant component in manufacturing optimization. The total optimal cost of 2,137,450 TL represents a significant improvement over traditional planning methods, as demonstrated in similar optimization studies by Qin and Geng (2013) and Tosello et al. (2019). This approach aligns with cost optimization principles established by Michalakoudis et al. (2016).

The strategic use of inventory to manage seasonal demand fluctuations, particularly for trousers, supports the findings of Banerjee and Sharma (2010), who identified inventory build-up as a cost-effective strategy for managing predictable demand peaks. This approach is further validated by Rodriguez and Vecchietti (2010) in their supply chain optimization study. Similarly, the minimal use of overtime production aligns with cost optimization principles established in the literature (Kandemir, 2022; Sharma et al., 2019).

In conclusion, this study demonstrates that mathematical optimization techniques can effectively address production planning and inventory management challenges in the textile industry. The findings contribute to the existing literature by providing empirical evidence of the benefits of integrated production and inventory planning in a seasonal demand environment. Future research should address the limitations of this study by incorporating demand uncertainty and time-varying costs to further enhance the applicability of optimization models in textile manufacturing.

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Conflict of Interest

The authors have declared that there is no conflict of interest.

Author Contributions

Both authors contributed equally to all aspects of this research including conceptualization, methodology, data collection, analysis, and writing of the manuscript.