Chapter 3

Multi-Period Production and Inventory Planning in Textile Industry: A Case Study of Textile Company

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Abstract

In the textile sector, seasonal demand fluctuations and variable raw material prices increase the strategic importance of production and inventory planning. In this study, a mathematical model has been developed to optimize the production and inventory planning for a three-month period of a textile company operating in Turkey. The model aims to minimize normal working hours, overtime, and inventory holding costs for three main product groups: T-shirts, trousers, and shirts. The mathematical model, solved using LINGO software, optimizes the company's three-month (June-August 2025) production and inventory planning. In the study, demand forecasts, labor requirements, minimum stock levels, and maximum storage capacity constraints were defined for each product. According to the optimization results, an optimal production and inventory plan was obtained with a total cost of 2,137,450 TL. This plan envisages production of 7,800 units for T-shirts, 4,200 units for trousers, and 4,650 units for shirts. Capacity utilization analysis showed that normal working hour capacity was utilized at 100%, while overtime capacity was used at 55% only in August for T-shirt production. Stock level analysis revealed that minimum stock levels were maintained for T-shirts and shirts, while high stock levels were maintained for trousers in June and July in preparation for high demand in August. Cost analysis showed that 91.3% of the total cost consisted of normal working hour production costs, 7.4% of overtime costs, and 1.3% of inventory holding costs. As a result of the study, strategic recommendations were presented

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regarding the company's production capacity management, inventory optimization, cost reduction, and demand management. The presented model is adaptable to other enterprises in the textile sector and provides a scientific approach to production and inventory planning decisions suitable for seasonal demand fluctuations.

INTRODUCTION

The textile industry faces significant challenges in production planning and inventory management due to seasonal demand fluctuations, variable raw material costs, and intense market competition. Effective production planning is crucial for textile manufacturers to maintain profitability while meeting customer demands in a timely manner (Singh and Chadha, 2016). This study addresses the production and inventory planning challenges of a textile company operating in Turkey, focusing on optimizing production schedules and inventory levels over a three-month planning horizon.

The textile sector in Turkey represents a significant portion of the country's manufacturing industry and export revenue. However, companies in this sector often struggle with balancing production capacity, inventory costs, and meeting fluctuating customer demands (Erdil and Erdil, 2017). Traditional production planning approaches frequently result in either excess inventory, leading to increased holding costs, or insufficient production, resulting in lost sales opportunities and decreased customer satisfaction.

Linear programming and mathematical optimization techniques have been widely applied in manufacturing industries to address production planning problems. These techniques allow companies to determine optimal production quantities, inventory levels, and resource allocation while considering various constraints such as production capacity, storage limitations, and demand requirements. Previous studies have demonstrated that mathematical optimization can lead to significant cost savings and operational improvements in manufacturing environments (Krynke, M., & Mielczarek, 2018; Perez et al., 2021).

This study aims to develop and implement a multi-period production and inventory planning model for a textile company in Turkey. The model focuses on three main product categories: T-shirts, trousers, and shirts, with the objective of minimizing total production, overtime, and inventory holding costs while satisfying customer demand over a three-month planning horizon (June-August 2025). The results provide valuable insights for production managers and decision-makers in the textile industry regarding capacity utilization, inventory management, and cost optimization strategies.

MATERIAL AND METHODS

Material

The material for this study consists of production and inventory data from a textile manufacturing company operating in Turkey. The company produces three main product categories: T-shirts, trousers, and shirts, and experiences significant seasonal demand fluctuations. The planning horizon covers three months (June-August 2025), for which detailed demand forecasts were provided by the company's marketing department based on historical sales data and market trends.

The dataset includes comprehensive information on product specifications, labor requirements, production costs, inventory holding costs, and capacity constraints. This information was collected through structured interviews with production managers and analysis of the company's Enterprise Resource Planning (ERP) system records. The company's production facility operates with both regular time and overtime capacity, with different associated labor costs.

For each product category, specific parameters were identified including unit production costs, labor hours required per unit, inventory holding costs per unit per month, initial inventory levels, and minimum required inventory levels. These parameters form the foundation of the mathematical optimization 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, inventory manager, and finance director. These interviews provided insights into the operational constraints, cost structures, and strategic priorities of the company.

Secondary data was extracted from the company's ERP system, covering historical production records, inventory levels, demand patterns, and cost information for the past three years. This historical data was essential for validating the parameters used in the optimization model and for assessing the seasonal patterns in demand.

Demand forecasts for the three-month planning horizon were developed using a combination of time series analysis, moving average methods, and expert judgments from the sales department. The forecasts were validated against historical accuracy metrics to ensure reliability.

Production capacity data was collected through time studies and analysis of production line capabilities. Regular time capacity was established at 4,000 hours per month, while maximum overtime capacity was set at 1,200 hours per month. Labor costs were determined based on current wage rates and overtime premium policies.

Statistical Analysis

A linear programming model was formulated to optimize the production and inventory planning decisions. The model was implemented using LINGO optimization software version 19.0, which employs the simplex method for solving linear programming problems and branch-and-bound techniques for integer programming components.

The mathematical formulation of the model includes an objective function that minimizes the total cost, which comprises regular time production costs, overtime production costs, and inventory holding costs:

This mathematical model has been compiled from similar studies in the literature (Chan et al., 2017; Sepehri et al., 2021).

Sets and Indices

$U=\{1,2,3\}:U=\{1,2,3\}:$ Product set; $u=1;u=1$:T-shirt, $u=2;u=2:$ Trousers, $u=3;u=3:$ Shirt

$A=\{1,2,3\}:A=\{1,2,3\}:$ Month set; $a=1;a=1:$ June, $a=2;a=2:$ July, $a=3;a=3:$ August

Parameters

d_{ua} : Demand quantity for product u in month a (units)

h_u : Unit inventory cost for product u (TL/unit/month)

p_u : Unit production cost for product u (TL/unit)

l_u : Unit working time requirement for product u (hours/unit)

c_a^n : Normal working capacity in month a (hours)

c_a^o : Overtime working capacity in month a (hours)

w^n : Normal working unit cost (TL/hour)

w^o : Overtime working unit cost (TL/hour)

i_u^0 : Initial inventory level for product u (units)

i_u^{min} : Minimum inventory level for product u (units)

C^{max} : Maximum total warehouse capacity (units)

Decision Variables

x_{ua}^n : Quantity of product u produced in month a during normal hours (units)

x_{ua}^o : Quantity of product u produced in month a during overtime (units)

i_{ua} : Inventory level of product u at the end of month a (units)

Objective function:

$$Min\,Z = \sum_{u \in U} \sum_{a \in A} (w^n \cdot l_u \cdot x_{ua}^n + w^o \cdot l_u \cdot x_{ua}^n + h_u \cdot i_{ua}) \tag{1}$$

Object to:

$$\sum_{u \in U} l_u \cdot x_{ua}^n \le c_a^n \qquad \forall_{a \in A} \tag{2}$$

$$\sum_{u \in U} l_u \cdot x_{ua}^o \le c_a^o \qquad \forall_{a \in A} \tag{3}$$

$$i_{u1} = i_u^0 + x_{u1}^n + x_{u1}^o - d_{u1} \qquad \forall_{u \in U} \tag{4}$$

$$i_{ua} = i_{u,a-1} + x_{ua}^n + x_{ua}^o - d_{ua} \qquad \forall_{u \in U}, \forall_{a \in A}, A \setminus \{1\} \tag{5}$$

$$i_{ua} \ge i_u^{min} \qquad \forall_{u \in U}, \forall_{a \in A} \tag{6}$$

$$\sum_{u \in U} i_{ua} \le C^{max} \qquad \forall_{a \in A} \tag{7}$$

$$x_{ua}^n, x_{ua}^o, i_{u,a} \in \mathbb{Z}^+ \qquad \forall_{u \in U}, \forall_{a \in A} \tag{8}$$

Equation (1) represents the objective function that minimizes total production, working, and inventory costs. Equation (2) ensures normal working capacity constraints are not exceeded in each month. Equation (3) ensures overtime working capacity constraints are not exceeded in each month. Equation (4) defines inventory balance for the first month. Equation

(5) defines inventory balance for subsequent months. Equation (6) ensures minimum inventory levels are maintained. Equation (7) ensures maximum warehouse capacity is not exceeded. Equation (8) enforces non-negativity and integer requirements for all decision variables.

RESULTS

The optimization model was successfully solved, yielding an optimal production and inventory plan for the three-month planning horizon. The total cost of the optimal solution was 2,137,450 TL, which includes regular time production costs, overtime production costs, and inventory holding costs.

Production Plan

The optimal production quantities for each product and time period are presented in Tables 1 and 2, distinguishing between regular time and overtime production.

Table 1. Regular Time Production (Units)

Product	June	July	August
T-shirts	2,200	3,800	480
Trousers	1,850	750	1,600
Shirts	850	1,500	2,300

Table 2. Overtime Production (Units)

Product	June	July	August
T-shirts	0	0	1,320
Trousers	0	0	0
Shirts	0	0	0

The results (Table 1 and Table 2) indicate that regular time production was prioritized across all periods, with overtime production only utilized for T-shirts in August. This aligns with cost-efficient production planning, as regular time production has a lower cost per unit compared to overtime production.

Inventory Levels

The optimal inventory levels at the end of each period are presented in Table 3.

Table 3. End-of-Period Inventory Levels (Units)

Product	Initial	June	July	August
T-shirts	500	200	200	200
Trousers	300	950	700	100
Shirts	200	150	150	150

The inventory levels (Table 3) show strategic inventory management decisions. For T-shirts and shirts, the inventory levels were maintained at the minimum required levels throughout the planning horizon, minimizing inventory holding costs. For trousers, higher inventory levels were maintained in June and July to prepare for the increased demand in August, demonstrating a build-up strategy.

Capacity Utilization

The capacity utilization for both regular time and overtime is presented in Tables 4 and 5.

Table 4. Regular Time Capacity Utilization

Month	Used (hours)	Total (hours)	Utilization Rate
June	4,000	4,000	100%
July	4,000	4,000	100%
August	4,000	4,000	100%

Table 5. Overtime Capacity Utilization

Month	Used (hours)	Total (hours)	Utilization Rate
June	0	1,200	0%
July	0	1,200	0%
August	660	1,200	55%

The capacity utilization analysis (Table 4) reveals that regular time capacity was fully utilized (100%) in all three months, indicating efficient use of available resources. Overtime capacity (Table 5) was only utilized in August (55%), specifically for T-shirt production, to meet the demand requirements while maintaining minimum inventory levels.

Cost Analysis

The breakdown of the total cost is presented in Table 6.

Table 6. Cost Breakdown

Cost Component	Amount (TL)	Percentage
Regular Time Production Cost	1,952,000	91.3%
Overtime Production Cost	158,400	7.4%
Inventory Holding Cost	27,050	1.3%
Total Cost	2,137,450	100%

The cost analysis (Table 6) shows that regular time production costs constitute the majority (91.3%) of the total cost, followed by overtime production costs (7.4%) and inventory holding costs (1.3%). This distribution reflects the model's emphasis on minimizing higher-cost components, particularly overtime production and inventory holding.

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 Zhang and Sun (2018), who emphasized the importance of maximizing regular time capacity before utilizing more expensive overtime production in manufacturing environments. This approach is supported by Ebrahim and Rasib (2017) and further validated by Fernandes et al. (2024) in their assessment of capacity adjustment strategies.

The inventory management strategies identified in this study reflect the principles of strategic inventory positioning discussed by Schwartz and Rivera (2010). 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 the assertion that product-specific inventory policies based on demand patterns yield superior results compared to uniform inventory strategies (Ziukov, 2015; Jauhari et al., 2023). This finding is consistent with advanced inventory management practices identified by Panigrahi et al. (2015).

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 Öztürk (2021), who identified production costs as the dominant component in manufacturing optimization systems. The total optimal cost of 2,137,450 TL represents a significant improvement over traditional planning methods, as demonstrated in similar optimization studies by Strub et al. (2021) and supported by cost analysis principles established by Gim and Yoon (2012).

The strategic use of inventory to manage seasonal demand fluctuations, particularly for trousers, supports the findings of Mattsson (2010), who identified inventory build-up as a cost-effective strategy for managing predictable demand peaks. This approach is further validated by Namwad et al. (2024) in their optimization study and Nambiar et al. (2021) in their dynamic inventory allocation research. Similarly, the minimal use of overtime production aligns with cost optimization principles established in the literature.

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.