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INVENTORY MANAGEMENT BASED ON DEMAND FORECASTING IN STORE WAREHOUSES

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INTRODUCTION

KOTON Retail Textile Trade and Industry Inc. was founded in Istanbul in 1988 by Yılmaz Yılmaz and Gülden Yılmaz. was founded in Istanbul in 1988 by Yılmaz Yılmaz and Gülden Yılmaz. Today, it operates with 220 designers and more than 60,000 product types. The company, which opened its first overseas store in Munich in 1996, offers online sales in 55 countries and serves in a total of 451 stores. KOTON, which has competitors such as DeFacto, LC Waikiki and Mavi, continues to grow with its mission of adding value to people and society.

THE SYSTEM UNDER CONSIDERATION

KOTON is an important clothing brand that adopts the fast fashion strategy in Turkey. KOTON, which has 242 stores in 65 cities, works with contract manufacturers based in Istanbul and distributes its products to the stores from the main warehouse in Gebze. Operations are carried out through a coordinated system that starts with market research and includes product development, procurement, sales planning, store operations and stock tracking processes. Product and stock tracking is done using SAP software, and product transfer is carried out in a planned manner every week.

PROBLEM DEFINITION

KOTON is a retail company based in Istanbul that works with contract manufacturers and offers a wide range of products. Products are distributed from the main warehouse in Gebze to 242 stores across Türkiye. Unprocessable stocks accumulating in store warehouses complicate operational processes by causing inventory errors and additional costs. Inter-store transfers are ineffective and products are returned to underperforming stores. Shipment from a single-center warehouse is insufficient to meet demands quickly and makes logistics operations difficult. As a result, the main problem that KOTON faces is that the right product cannot be found at the right time and in the right place. Therefore, KOTON needs better planning and strategies in stock management and product shipment.

OBJECTIVE OF THE PROJECT

The main purpose of this project is to prevent excess stock, ensure that products are placed on the shelves on time, and increase warehouse efficiency and space utilization. It also aims to improve the distribution process between warehouses and stores by determining data-based demand forecasting and optimum stock levels.

METHODOLOGY

Figure 1. Process of Project

Data Collection: Within the scope of the project, factors such as store-based sales data from previous years, store capacity, customer profile, weather conditions, and special day campaigns were collected and analyzed.

S**election of Product Classes:** The project focused on the product classes that contribute the most to sales volume and turnover. With the XYZ analysis, the product classes with the highest turnover volume were determined and the AX group product classes, which constitute 80% of the sales volume and 80% of the turnover volume, were identified. Ultimately, 28 product classes to focus on were identified.

Data Preprocessing: The data set was organized to include product information and prepared for analysis. Data cleaning, separation of variables, scaling, coding, feature selection, and correlation analysis were performed. The data set is divided into 80% training and 20% testing.

Clustering: The focus is on 213 stores with active sales in 2022 and 2023. With the K-Means algorithm, stores in 65 provinces were clustered, and similar product groups and sales were brought together, enabling more effective analysis.

Demand Forecasting: XGBoost, artificial neural networks, multiple linear regression, and random forest algorithms were used for demand forecasting. Prediction results were evaluated by Mean Absolute Deviation (MAD) and R Square (R^2).

Determining Inventory Level - Mathematical Model

Indices

i week from 8 to 49

j type of the product from 1 to 28

f type of truck from 1 to 3

Parameters

H_j Holding cost of product type of j

T_f Setup cost of truck type of f

D_{ji} Demand of j th product at week i

C_j Cost of product j

B_f Capacity of f type of truck

P_j Volume of product j

Z_j Safety stock for j th product

R Capacity of the store (Forum 857)

Decision Variables

X_{if} Amount of truck that comes to store at i th week(integer)

A_{ij} amount of j th product type replace to store at i th week

S_{ij} Amount of product that is kept in store at i th week

Objective Function

$$\min \sum_i \sum_j S_{ij} H_i + \sum_i \sum_f X_{if} T_f$$

Constraints

$$S_{1j} = Z_j \qquad (1)\ \text{beginning inventory level for each } \mathbf{j}$$

$$\sum_j S_{ij} P_j \leq R \qquad (2)\ \text{volume of store for each } \mathbf{i} \text{ and } i \neq 1$$

$$A_{ij} + S_{i-1j} - D_{ji} = S_{ij} \qquad (3)\ \text{flow balance for each } \mathbf{i}, \mathbf{j} \text{ and } i \neq 1$$

$$S_{ij} \geq Z_j \qquad (4)\ \text{inventory includes safety stock for each } i, j \text{ and } i \neq 1$$

$$\sum_f X_{if} B_f \geq \sum_j A_{ij} P_j \qquad (5)\ \text{determining number of truck for each } \mathbf{i} \text{ and } i \neq 1$$

Figure 2. Mathematical Model

INDUSTRIAL ENGINEERING

KOTON

RESULT

Clustering Results

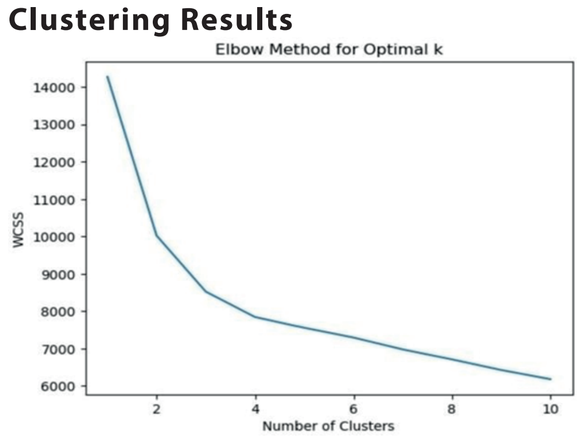

Figure 3. Elbow Result of 2022

The clustering method was applied separately for both 2022 and 2023. The results stated below are the results of 2022.

According to the results of the Elbow Method, the elbow break points in the chart are determined as 2, 3, and 4. According to the Elbow Method analysis result, the most appropriate cluster number (k) value was determined as 4. Based on this, 4 clusters were created using the K-Means algorithm.
These 4 clusters are shown below.

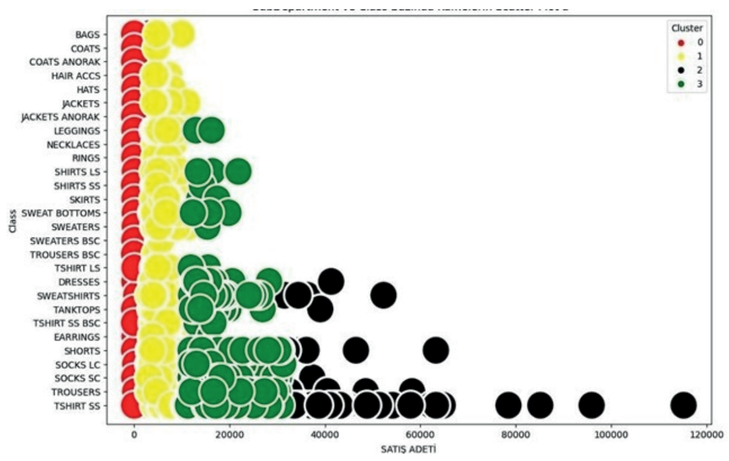

Figure 4. Clustering Result of 2022

When the 2022 clustering results above are examined, the red cluster 0 in the chart represents newly opened or closed stores, the yellow cluster 1 represents low-selling stores, the green cluster 3 represents medium-selling stores, and the black cluster 2 represents high-selling stores. This analysis shows that the clustering algorithm identifies product classes with similar sales volumes using sales data.

Demand Forecasting Results

To perform demand forecasting for Koton, four different machine learning methods were used: Random Forest, XG Boost, Artificial Neural Networks (ANN), and Multiple Linear Regression (MLR). Each of these methods was applied to a specific data set and the results were compared. R-squared values are shown in the table below.

	ANN		XG BOOST		RANDOM FOREST		MLR	
CLASS	(-) CLUSTERS	(+) CLUSTERS	(-) CLUSTERS	(+) CLUSTERS	(-) CLUSTERS	(+) CLUSTERS	(-) CLUSTERS	(+) CLUSTERS
SHORTS	0.691	0.694	0.421	0.437	0.798	0.789	0.313	0.313
SKIRTS	0.515	0.514	0.390	0.390	0.524	0.542	0.378	0.378
SOCKS LC	0.838	0.842	0.662	0.667	0.813	0.820	0.538	0.539
SOCKS SC	0.831	0.843	0.660	0.692	0.841	0.845	0.615	0.615
SWEAT BOTTOMS	0.593	0.593	0.413	0.411	0.637	0.641	0.373	0.373
SWEATERS	0.652	0.650	0.399	0.399	0.715	0.731	0.275	0.275
SWEATERS BSC	0.653	0.653	0.548	0.548	0.700	0.717	0.324	0.324
SWEATSHIRTS	0.523	0.525	0.357	0.396	0.582	0.578	0.336	0.336
TANKTOPS	0.728	0.731	0.428	0.436	0.777	0.779	0.405	0.405
TROUSERS	0.847	0.855	0.624	0.696	0.877	0.880	0.511	0.511
TROUSERS BSC	0.688	0.685	0.517	0.517	0.632	0.604	0.466	0.466
TSHIRT LS	0.764	0.763	0.417	0.417	0.771	0.773	0.379	0.379
TSHIRT SS	0.458	0.475	0.420	0.459	0.582	0.592	0.399	0.399
TSHIRT SS BSC	0.233	0.237	0.413	0.413	0.304	0.266	0.254	0.254

Figure 5. R-squared Values of Methods

The Random Forest method showed the highest performance in Koton company's demand forecasting studies. The analysis revealed that this method was successful in capturing complex sales patterns in the fashion retail industry and that its clustering features increased the forecasting performance. In this regard, it is recommended to use the Random Forest method in demand forecasting and inventory management processes.

Mathematical Model Results

This project was implemented to cover all Koton stores in Turkey. The results obtained from the Kayseri Forum store in the best-selling store category are presented as an example. The results were examined using the 2023 data of the stores.

The objective function of the created mathematical model is to minimize the total cost. However, the minimized cost in the problem includes the holding cost of the trucks and the installation costs. It took the model approximately 20 hours to reach the optimal result.
The total cost is approximately 2313461 TL.

	Before	Proposed Solution	Improvement(%)
Holding Cost	1.111.000	35.461	96,80%
Set-up Cost	1.680.000	2.278.000	-35,59%
Total Cost	2.791.000	2.313.461	17,11%

Figure 6. Improvements Result of Kayseri Forum Store

As a result of the improvements made, the stock holding cost of the Kayseri Forum store decreased by 96%, while the set-up cost increased by 35%. However, the total cost decreased from 2,791,000 TL to 2,313,461 TL, resulting in an improvement of 17%.

Interface Design Results

The developed interface aims to provide an intuitive user experience by integrating Koton's demand forecasts with optimum stock levels. It includes three main functions: Custom Calculation, City-Based Calculation, and Store-Based Working.

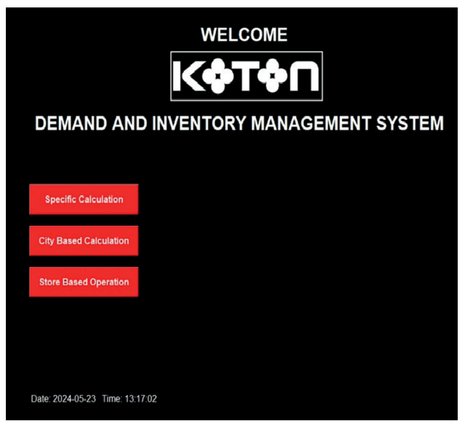

Figure 7. Interface

This study emphasizes the importance of a chain operating in the retail sector in adapting to rapidly changing consumer expectations and a competitive environment. The project focuses on the innovations brought by artificial intelligence and mathematical models to stock management and forecasting processes, as well as traditional methods. Through data preparation, cluster analysis, machine learning models, and mathematical model applications, the organization has improved inventory management and meeting consumer demands by making better decisions.

CONCLUSION

This study emphasizes the importance of a chain operating in the retail sector in adapting to rapidly changing consumer expectations and a competitive environment. The project focuses on the innovations brought by artificial intelligence and mathematical models to stock management and forecasting processes, as well as traditional methods. Through data preparation, cluster analysis, machine learning models, and mathematical model applications, the organization has improved inventory management and meeting consumer demands by making better