A Comprehensive Approach to Fuel Price Estimation and Operational Optimization of the Fuel Station for Boytrans Logistics

2023-2024 Academic Year
Yousef Adawiya/ Hüseyin Altınsoy/ Firdevs Sude Çelik/ Halef Çoban/
Academic Supervisor: Dr. İsmet SÖYLEMEZ /
Company Supervisor: Arman Çağrı YETİŞEN /
ABDULLAH GÜL UNIVERSITY
DEPARTMENT OF INDUSTRIAL ENGINEERING

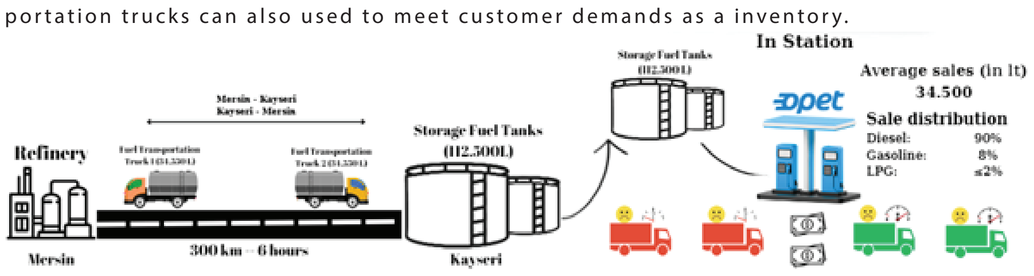
1 INTRODUCTION

Boytrans Logistics started its operations in 1996 with the aim of providing logistics services to Erciyes Anadolu Holding Group Companies with 10 self-owned vehicles.
Over time, it has become a leading logistics company in its sector, providing domestic service with 100+ tractors, 170+ trailers, 400+ passenger vehicles and fuel stations, and providing air, land, rail and sea import-export organization to various countries of the world.

2 CURRENT SYSTEM

Boytrans is getting the fuels from Mersin using 2 Fuel transport trucks which goes nearly 7 times weekly to Mersin to take all fuel types from storage station.

Boytrans has a total of 5 storage fuel tanks, each with a capacity of 22.500 liters. Also, they have a total of 2 fuel transportation trucks, each with a capacity of 34,500 liters. daily sales of Boytrans are 90% of the selling is only for diesel. The capacity of transportation trucks can also used to meet customer demands as a inventory.



3 PROBLEM DEFINITION

The lack of a reliable forecasting system leads to inefficiencies in fuel supply and logistics management, negatively affecting profitability and operational efficiency. The absence of a predetermined weekly schedule to determine which truck(s), how much purchasing of fuel quantities and what days for fuel purchases for two fuel transportation trucks.

4 PROJECT OBJECTIVE

The project aims to prevent profit loss from fuel price uncertainty in Turkey and develop a forecasting system for Boytrans. Using Python and machine learning, we aim to predict diesel prices and minimize total costs through MILP modeling. Python GUROBI solver used for optimization.

5 METHODOLOGY 1

The primary aim is to predict diesel prices in Turkey using a robust, data-driven methodology. This involves data collection, pre-processing, correlation analysis, model selection, evaluation, cross-validation, and training/test set assessment.
Correlation analysis uncovers strong links between diesel prices and variables like USD/TRY exchange rates, CPI, and Crude Oil Prices, guiding modeling.
K-fold cross-validation ensures unbiased evaluation of the Random Forest model's predictive power across data subsets, guarding against overfitting and underfitting.
Testing on separate datasets confirms the Random Forest model's strong predictive ability with minimal overfitting.

Varibales	Correlations
Date	88%
KDV	58%
OTV	66%
USD	95%
TUFE	47%
USAGE	6%
CRUDE OIL	-7%
PRICE	100%

Table: Variables and Correlations

Model	MAE	MSE	RMSE	R-squared (R^2)
Linear Regression	2,05	7,92	2,81	0,91
Ridge Regression	2,03	7,96	2,82	0,91
Random Forest	0,03	0,08	0,28	1,00
Gradient Boosting	0,15	0,12	0,34	1,00
SVR	0,79	1,90	1,38	0,98
KNN	0,00	0,00	0,02	1,00
ARIMA	8,71	133,76	11,57	NaN
LSTM	0,84	2,11	1,45	NaN
F-NN	0,35	0,28	0,53	NaN

Table:: Models and Metrics

Fold	MSE	MAE	RMSE	R^2
1	0,002	0,009	0,039	1,000
2	0,125	0,057	0,353	0,999
3	0,118	0,038	0,343	0,999
4	0,117	0,046	0,342	0,999
5	0,063	0,046	0,250	0,999
AVG	0,085	0,039	0,266	0,999

Table: K-fold cross-validation of Random Forest Model

RF-ER-Metrics	Training Set	Test Set
Mean Squared Error	0,013	0,070
Mean Absolute Error	0,016	0,032
Root Mean Squared Er	0,114	0,265
R-squared (R^2)	1,000	0,999

Table: Both Training and Test Data Performance Results

6 METHODOLOGY 2

This methodology section outlines the linear programming model developed for optimizing the diesel fuel delivery operations of Boytrans over a one-week period. The objective is to minimize the total cost associated with purchasing and transporting diesel fuel, while ensuring the daily demand at the fuel station is met and maintaining necessary safety stock levels.

Indices

i: Set of trucks (i=1,2)

j: Set of days (j=1,2,3,4,5,6,7)

Parameters

C: Capacity of truck. (liters)

T: Total capacity of tanks in fuel station. (liters)

P_j: Predicted price of diesel in day j. (TL/liters)

D_j: Demand of diesel in day j. (liters)

Min: Minimum safety stock of diesel in fuel station. (liters)

F_i: Total transportation cost of truck i. (TL)

K: Total amount of fuel transferred to the first day of the Week. (liters)

Decision Variables

I_j: Fuel station depot inventory level after satisfying demand on day j. (liters)

x_{ij}: 1 if the truck i goes to Mersin on day j, 0 ow.

y_{ij}: The amount of diesel taken from Mersin by truck i in day j. (liters)

b_{ij}: The amount of diesel that truck i unloaded to the station on day j. (liters)

z_{ij}: The amount of diesel stored (separately) at day j without discharging it at the station. (liters)

Objective Function

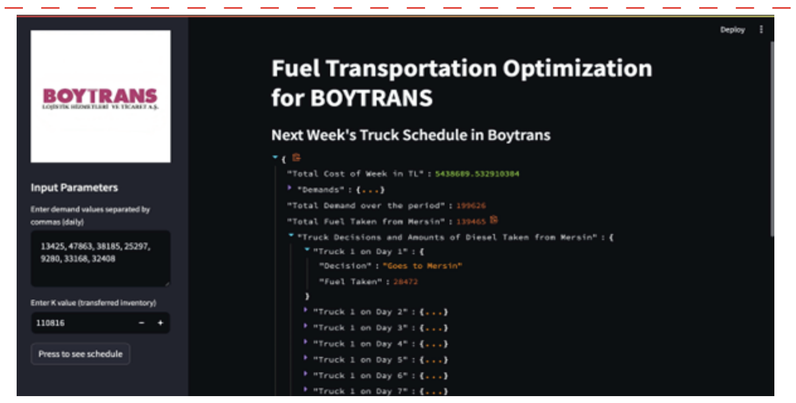
$$Min \sum_{i}^{2}\sum_{j}^{7}(y_{ij}P_j) + (x_{ij}F_i)$$

Constraints

1. Inventory in the fuel station after supplying demand.
$$I_j = I_{j-1} + \sum_{i}^{2}(b_{ij} + z_{ij-1}) - D_j \qquad \forall_{j=2,\dots,7}$$
2. Initial inventory includes transferred furl plus unloaded to station minus demand.
$$I_1 = K + \sum_{i}^{2} b_{i1} - D_1$$
3. Safety stock in Fuel Station
$$I_j + \sum_{i}^{2} z_{ij} \geq Min \qquad \forall_j$$
4. Summation of inventory and taken fuel must be higher than the demand.
$$I_{j-1} + \sum_{i}^{2}(y_{ij}) \geq D_j \qquad \forall_{j=2,\dots,7}$$
5. First day station inventory and taken fuel must be higher than the demand.
$$K + \sum_{i}^{2}(y_{i1}) \geq D_1$$
6. Amount of fuel stored (separately) in truck.
$$z_{ij} = y_{ij} - b_{ij} \qquad \forall_{ij}$$
7. The unloaded fuel in truck cannot exceed the taken fuel from Mersin.
$$b_{ij} \leq y_{ij} \qquad \forall_{ij}$$
8. If truck has an inventory, truck cannot go to Mersin another day.
$$x_{ij} \leq 1 - \frac{z_{ij-1}}{C} \qquad \forall_{i=2,\dots,7}, \forall_j$$
9. Fuel station inventory cannot exceed the capacity of fuel station.
$$I_j \leq T \qquad \forall_j$$
10. If the truck goes to Mersin, take the fuel with the capacity of the truck.
$$y_{ij} \leq x_{ij}C \qquad \forall_{i,j}$$
11. Non-Negativity Constraints
$$y_{ij}, I_j, z_{ij}, b_{ij} \geq 0 \qquad \forall_{i,j}$$
12. Binary Constraint
$$x_{ij} = \{0,1\} \qquad \forall_{i,j}$$

7 INTERFACE

For our project, an interactive interface was developed using Streamlit library in Python to solve a linear programming (LP) optimization problem concerning the truck scheduling for Boytrans Logistics. This interface allows users to input specific parameters related to daily fuel demands and transferred inventory, thereafter generating an optimized schedule for fuel delivery.



Interface of Truck Schedule

8 RESULTS

The project successfully developed a methodology for predicting diesel prices in Turkey using Random Forest, which showed exceptional accuracy. Additionally, a Streamlit interface was created for user interaction with the model. An optimized truck scheduling model was also developed for Boytrans Logistics to minimize transportation costs while meeting daily fuel demands.

Configuration	Trips Required	Total Cost	Profit Earned
Boytrans *(Current System)*	8	₺6,165,256.10	-
Optimized Model *(Two Trucks)*	5	₺5,988,237.00	₺177,019.10
Optimized Model *(One Truck)*	5	₺5,999,277.00	₺165,979.10

Comparison of project results and current system

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