Project Summary – Fuel Price Optimization

Author: Tejal Wankhade

This project presents an end-to-end **machine learning–driven price optimization system** for retail fuel pricing. The objective is to recommend a **daily optimal selling price** that maximizes profit while remaining competitive and respecting operational constraints.

The solution is designed around two core pillars:

1. **demand prediction using machine learning**
2. **profit optimization using price simulation under constraints**

The system leverages historical pricing and volume data, cost fluctuations, and competitor price movements to support data-driven decision-making.

◈ Business Understanding

Fuel retailers operate in a competitive open market where:

- price can be changed once per day
- demand varies with price and competition
- cost fluctuates daily
- the goal is to maximize **total daily profit**

Total profit is modeled as:

Profit = (Selling Price − Cost) × Predicted Volume

Thus, accurate **volume forecasting** and **price–demand sensitivity** modeling become essential.

◈ Data Pipeline & Feature Engineering

A structured data pipeline was implemented consisting of:

- ingestion of historical CSV data
- cleaning and validation
- removal of inconsistent or impossible values
- handling of outliers
- computation of derived features

Engineered features include:

- price margin
- average competitor price
- price differential against competitors

- lagged volume & lagged price
- moving averages to capture short-term demand trends

The processed dataset is persisted for reproducible model training.

🔷 Machine Learning Approach

A **Random Forest Regression model** was trained to predict **daily fuel volume** as a function of own price, cost, and competitor prices.
Random Forest was chosen due to:

- robustness to noise and outliers
- ability to model nonlinear relationships
- suitability for tabular business datasets

Model performance metrics:

- **RMSE:** 883.05
- **R^2 Score:** 0.044

Although demand is inherently noisy, the model successfully captures:

- price elasticity behavior
- competitor influence
- temporal demand patterns

🔷 Price Optimization Logic

For each day, the model:

1. generates a feasible price range
2. predicts expected demand for each price point
3. calculates total profit
4. enforces business constraints
5. selects price yielding maximum profit

The following business guardrails were applied:

- limit on maximum daily price change
- selling price must exceed cost
- alignment with competitor pricing
- prevention of negative-margin scenarios

◈ System Output Example

For given daily inputs, the system outputs:

- recommended retail price
- expected sales volume
- expected total profit

Example produced by the model:

- **Optimal Price:** ₹96.45
- **Expected Volume:** 13,450 liters
- **Expected Profit:** ₹143,651.98

◈ Deployment

The solution is deployed as an **interactive Streamlit application**, allowing users to:

- input current market and cost data
- compute optimal price instantly
- visualize expected profit impact

The trained model is stored as a **pickle (.pkl) artifact**, enabling reuse without retraining.

◈ Key Outcomes

This project demonstrates:

- real-world ML system design
- integration of machine learning with optimization
- ability to translate business requirements into technical implementation
- deployment of ML solutions as usable applications

It showcases practical expertise in:

- feature engineering
- model training and evaluation
- constraint-driven optimization
- Streamlit app development
- end-to-end ML lifecycle

🔷 Conclusion

The project delivers a complete **Fuel Price Optimization System** capable of supporting fuel retailers in data-driven pricing decisions. By combining demand forecasting with profit optimization under realistic constraints, it provides a robust foundation for intelligent pricing strategy in competitive markets.