DESIGN PRESENTATION

Advanced Supply Trade Resource Optimization
(A.S.T.R.O.)

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Introduction

- The project develops a platform that helps small-scale vendors compete with large retail chains by enabling collaborative purchasing and optimized logistics.
- The platform provides data-driven financial services, empowering vendors to make informed decisions, achieve bulk pricing, and enhance local economic resilience.

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Problem Definition

- **Problem :**
  Small-scale vendors struggle to compete with large retail chains due to limited purchasing power, inefficient logistics, and restricted access to financial services. These challenges prevent them from managing demand fluctuations effectively, securing competitive pricing, and making data-driven business decisions.
- **Solution :**
  Our platform empowers small-scale vendors by enabling collaborative purchasing to achieve bulk discounts, optimizing logistics to reduce costs, and providing data-driven financial services. This solution enhances vendors' competitiveness, allowing them to make informed decisions and thrive in the market.

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Scope and Motivation

Scope:
- Development of a platform for small-scale vendors.
- Features include user registration, order aggregation, and real-time demand management.
- Vendors can collaborate on orders to achieve bulk pricing.
- Integrated logistics optimization and data-driven financial services.

Motivation:
- Empower small-scale vendors to compete with large retail chains.
- Enhance economic resilience and sustainable growth in local communities.
- Provide vendors with tools for informed decision-making and operational efficiency.

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Target Groups

- **Small-Scale Vendors**: Independent businesses aiming to compete with large retail chains through cost-effective purchasing and logistics.
- **Local Suppliers**: Providers seeking to increase sales by collaborating with multiple vendors.
- **Platform Administrators**: Users managing vendor and supplier interactions, order coordination, and logistics optimization.

Objectives

1. **Enable Collaborative Purchasing :**
   - Develop a platform for small vendors to combine orders, securing bulk pricing and discounts.
2. **Optimize Logistics :**
   - Implement algorithms to improve delivery routes, reduce costs, and enhance efficiency.
3. **Real-Time Demand Forecasting :**
   - Use forecasting tools to help vendors anticipate demand and optimize inventory.

Challenges

- **Complex Models**: Requires tuning and resources for NeuralProphet and Genetic Algorithms.
- **High Computational Needs**: Limits real-time processing capabilities.
- **Scalability**: Managing performance as vendors, products, and locations grow.
- **Data Consistency**: Ensuring seamless data flow across forecasting, supplier selection, and logistics.

Resources Needed

- **Software Requirements :**
  - **OS :** Ubuntu / Windows / MacOS
  - **Frontend Library :** Flutter
  - **Backend Library :** Fast API
  - **IDE :** Visual Studio Code
  - **Programming language :** Python, Dart
  - **Containerization :** Docker
- **Dataset :**
  - Store Item Demand Forecasting Challenge – Kaggle Dataset (Kaggle Link)
- **Hardware Requirements :**
  - **CPU :** Ryzen 3 1200 – 3.1Ghz / Core i5-4460 – 3.2Ghz / Apple M1 chip
  - **RAM :** 8GB
  - **Video card :** AMD Raedon R9 380 / NVIDIA GeForce GTX 960 / Apple M1 chip 8-core GPU
  - **HDD :** 256 GB

LITERATURE REVIEW

X. Wang and L. Wang, "Green Routing Optimization for Logistics Distribution with Path Flexibility and Service Time Window," *2021 15th International Conference on Service Systems and Service Management (ICSSSM), Hangzhou, China, 2021*

Methods:

- **Path Flexibility**: Optimizes delivery routes by allowing flexibility in path choices, accounting for dynamic factors like traffic or road conditions.
- **Service Time Window**: Integrates delivery time constraints to ensure that products reach vendors or customers within the specified time windows for improved service.
- **Optimization Techniques**: Utilizes advanced optimization algorithms (such as genetic algorithms) to calculate the most efficient delivery routes while meeting all logistical constraints.

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- **Environmental Impact Consideration:** Focuses on minimizing carbon emissions through optimized route selection, reducing the environmental footprint of logistics operations.

Modules to Use for Project

- **Path Flexibility Module:** Allows for route adjustments in real-time based on varying factors (traffic, weather, etc.) to ensure timely deliveries.
- **Service Time Window Module:** Ensures that all deliveries are made within specified time frames, enhancing customer satisfaction and vendor reliability.

Advantages

- **Optimized Delivery Routes**: Minimizes time and distance, reducing operational costs.
- **Environmental Sustainability**: Lower emissions by selecting the most eco-friendly paths.
- **Scalability**: Efficiently handles logistics for various vendors and locations, adaptable to growth.

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- **Disadvantages**
  - **High Computational Demand**: Requires significant processing power for real-time optimization.
  - **Complex Algorithm Integration**: Involves combining various optimization techniques, which may be challenging to implement.
  - **Limited Real-Time Application**: May face challenges in providing immediate route changes due to computational constraints.

LITERATURE REVIEW

O. Triebe, H. Hewamalage, P. Pilyugina, N. Laptev, C. Bergmeir, and R. Rajagopal, "NeuralProphet: Explainable Forecasting at Scale," *arXiv preprint, Nov. 2021*

Methods

- **Hybrid Forecasting Model:** Combines Neural Networks and Classical Time-Series Models to capture complex patterns in demand data.
- **Explainable Forecasting**: Decomposes forecasts into trend, seasonality, and holiday effects, providing insights into what drives demand.
- **Scalability**: Designed to handle large-scale datasets efficiently, making it ideal for forecasting across multiple stores and items in the vendor collaboration platform.

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Modules Utilized in the Project

- **Demand Forecasting Module**: Uses NeuralProphet to predict future sales at the item level for various stores.
- **Trend and Seasonality Decomposition**: Extracts and interprets the trend and seasonality components to optimize inventory and purchasing decisions.

Advantages

- **Accurate Forecasts**: Captures complex demand patterns for better stock management and purchasing decisions.

•**Scalable for Multiple Locations**: Efficiently handles demand forecasting across different store locations and multiple items.

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Disadvantages

- **High Computational Demand**: NeuralProphet requires significant processing power, especially for large datasets with complex patterns.
- **Complex Model Tuning**: The hybrid nature of the model requires expertise to fine-tune and optimize for best results.

Use Case in Vendor Collaboration Platform

- **Inventory Optimization**: Accurate demand forecasts allow vendors to align stock levels with predicted sales, reducing stockouts and excess inventory.

LITERATURE REVIEW

S. Ben Jouida and S. Krichen, "A Genetic Algorithm for Supplier Selection Problem Under Collaboration Opportunities," *Journal of Experimental & Theoretical Artificial Intelligence*, vol. 34, no. 1, pp. 53-79, Jan. 2022. doi: 10.1080/0952813X.2020.1836031.

Methods

- **Genetic Algorithm (GA)**: Uses evolutionary techniques to optimize supplier selection by considering various factors like price, quality, and collaboration opportunities.
- **Supplier Collaboration**: Evaluates potential supplier collaboration to maximize benefits such as bulk order discounts, cost savings, and optimized logistics.
- **Fitness Function**: A fitness function is defined based on multiple criteria, including cost minimization, supplier reliability, and the potential for joint ordering with other vendors.

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Modules Utilized in the Project

- **Supplier Selection Module**: Uses the Genetic Algorithm to identify the best suppliers based on multiple performance metrics and collaboration potential.
- **Collaboration Opportunity Module**: Optimizes joint orders between vendors to meet minimum order quantities (MOQ) for bulk discounts, leveraging genetic algorithms to explore the most cost-effective collaborative orders.

Advantages

- **Cost Optimization**: Selects suppliers that provide the best combination of cost, reliability, and collaborative potential.
- **Improved Supplier Collaboration**: Leverages collaboration opportunities between vendors to achieve bulk discounts and more favorable terms.

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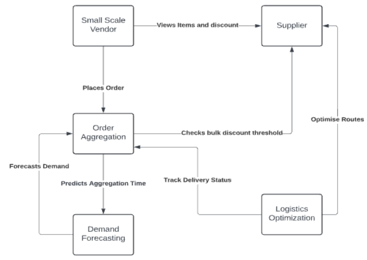
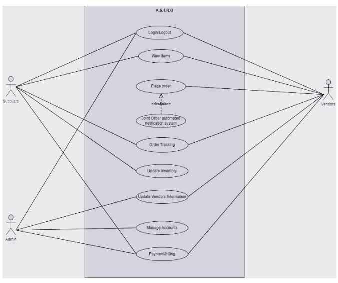
Disadvantages

- **Computational Intensity**: The genetic algorithm requires significant computational resources to evaluate many potential supplier combinations.
- **Complex Model Tuning**: The GA's parameters (e.g., population size, crossover rate) require fine-tuning to achieve optimal results.

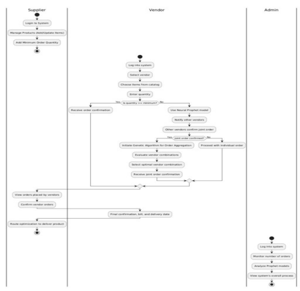
SYSTEM ARCHITECTURE



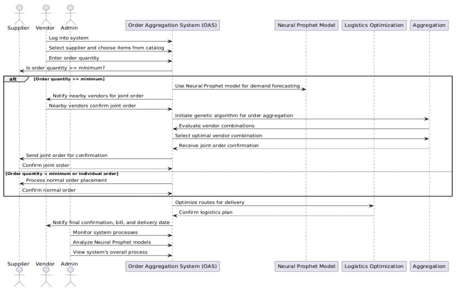
USE CASE DIAGRAM



ACTIVITY DIAGRAM



SEQUENCE DIAGRAM



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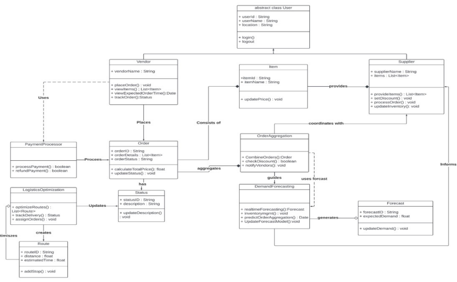
CLASS DIAGRAM



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Algorithms in Use-Route Optimization

- **Hybrid Demand Forecasting and Route Optimization Algorithm**

The Hybrid Demand Forecasting and Route Optimization Algorithm integrates demand forecasting with advanced route optimization techniques to enhance logistics efficiency. This algorithm ensures that vendor orders meet the bulk discount thresholds while optimizing delivery routes based on forecasted sales data.

Algorithm Steps

- **Define Bulk Discount Threshold**:
  - Establish the Minimum Order Quantity (MOQ) that must be reached for bulk discounts to apply.
  - Example: Set MOQ at 500 units.

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- **Forecast Vendor Demand**:
  - Utilize NeuralProphet to predict the expected daily sales for each vendor.

  Example:
    - Vendor A: 100 units/day
    - Vendor B: 150 units/day
    - Vendor C: 200 units/day
- **Aggregate Vendor Orders**:
  - Collect initial orders from all participating vendors based on the forecast data.
  - Formulate a list of order combinations to achieve the MOQ.
- **Calculate Cumulative Demand**:
  - Sum the sales from all vendors to determine total demand.
  - Monitor cumulative sales daily to ensure MOQ is met:

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- **Route Optimization Using Genetic Algorithm**:
  - **Initialize Routes**: Generate initial route combinations for deliveries based on vendor locations and demand.
  - **Fitness Evaluation**:
    - Evaluate routes based on factors like total distance, delivery time, and fuel costs.
    - Define a fitness score for each route based on these criteria
  - **Selection**:
    - Select the top-performing routes based on fitness scores.
- **Crossover and Mutation**:
  - Combine selected routes (crossover) to create new route combinations.
  - Introduce small changes (mutation) to explore potential improvements in route efficiency.

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- **Final Route Selection**:
  - After several iterations, converge on the optimal route(s) that minimize costs while meeting the bulk order requirements.
  - Ensure that the selected route(s) accommodate delivery timing and vendor locations efficiently.
- **Performance Benefits:**
  - **Cost Reduction**: Minimizes transportation costs through optimized routing.
  - **Efficiency**: Ensures timely deliveries by efficiently managing routes based on demand forecasts.
  - **Scalability**: Adapts to changing demand patterns and vendor participation in real-time.

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Algorithms In Use – Demand Forecasting

- **1. Define the Bulk Discount Threshold**
  - o The supplier typically sets a minimum order quantity (MOQ) or a bulk discount threshold that needs to be met before a bulk order is placed.
  - o Example: Supplier sets a bulk discount threshold of 500 units for a particular product.
- **2. Use Forecast Data for Sales**
  - o Use the forecasted sales data from NeuralProphet to estimate how much each vendor is likely to sell over time.
  - o Input: Forecasted sales from multiple vendors.
  - o Forecast Data Example:
    - ▪ Vendor A is expected to sell 100 units/day.
    - ▪ Vendor B is expected to sell 150 units/day.
    - ▪ Vendor C is expected to sell 200 units/day.

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- **3. Calculate Daily Cumulative Sales**
  - o Based on the forecasted sales, you can calculate the cumulative sales of all participating vendors.
  - o Cumulative Sales Example:
    - ▪ Day 1: 100 (A) + 150 (B) + 200 (C) = 450 units.
    - ▪ Day 2: 100 (A) + 150 (B) + 200 (C) = another 450 units.
  - o After 2 days, the cumulative sales would be 900 units, crossing the 500-unit bulk threshold.
- **4. Estimate the Aggregation Time**
  - o Once you have the daily cumulative sales forecasted, you can calculate when the bulk order threshold will be reached:

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- Expected Aggregation Time:
  - In the example, the threshold of 500 units is expected to be reached in just over 1 day (since 450 units are sold on Day 1 and an additional 50 units on Day 2 would meet the threshold).

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Algorithms In Use – Genetic Algorithm

Initialize Vendor Orders

- Start by gathering orders from multiple vendors based on their demand forecasting results. Each order includes quantity and expected sales.

Create Initial Population (Order Combinations)

- Generate an initial set of possible combinations of vendor orders that could meet the bulk order threshold. Each combination (solution) represents an aggregated order scenario.

Evaluate Fitness (Minimize Cost or Maximize Profit)

- For each order combination, evaluate its "fitness" by considering factors such as total cost, potential discounts, and logistics. Higher fitness means a better solution.

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Selection and Crossover

- Select the best-performing order combinations and combine them (crossover) to create new combinations. This step helps to find better solutions by mixing the strengths of different combinations.

Mutation and Final Solution

- Introduce small changes (mutation) to the order combinations to explore new possibilities. After several iterations, the algorithm converges to the most optimal aggregated order that maximizes vendor savings while meeting the bulk threshold.

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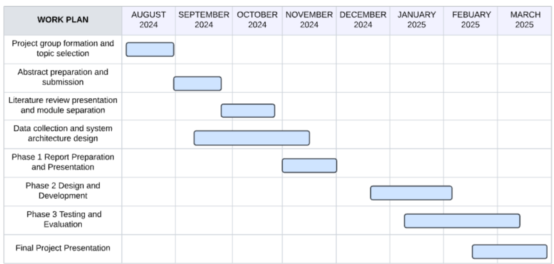
Work Plan



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Conclusion

- **Empowering Small Vendors**: Supports competitive edge through order aggregation and logistics optimization.
- **Key Achievements**: Accurate demand forecasting, eco-friendly routing, and cost savings via joint orders.
- **collaborative purchasing** :access to bulk discounts, improving supply chain efficiency.

References

- X. Wang and L. Wang, "Green Routing Optimization for Logistics Distribution with Path Flexibility and Service Time Window," *2021 15th International Conference on Service Systems and Service Management (ICSSSM), Hangzhou, China, 2021*
- O. Triebe, H. Hewamalage, P. Pilyugina, N. Laptev, C. Bergmeir, and R. Rajagopal, "NeuralProphet: Explainable Forecasting at Scale," *arXiv preprint, Nov. 2021*
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