

# INVENTORY OPTIMIZATION BASED ON DEMAND PREDICTION

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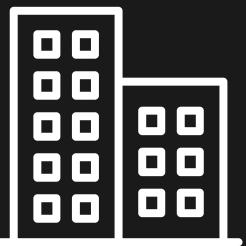
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# INTRODUCTION



In response to today's dynamic business landscape, our project emphasizes leveraging advanced analytics and machine learning for efficient supply chain management. By accurately predicting customer demand and optimizing inventory levels, we aim to reduce stockouts, minimize delivery times, and enhance overall operational efficiency.



Through this customer-centric approach, our goal is to deliver the right products at the right time, in the right quantities, ensuring heightened customer satisfaction and increased revenue.

# PROBLEM STATEMENT



## DEMAND PREDICTION

The project focuses on developing a robust demand prediction algorithm that utilizes historical business data to accurately forecast future demand. The algorithm aims to consider factors like seasonality, trends, and relevant patterns, providing reliable predictions for informed decision-making in inventory and supply chain management.

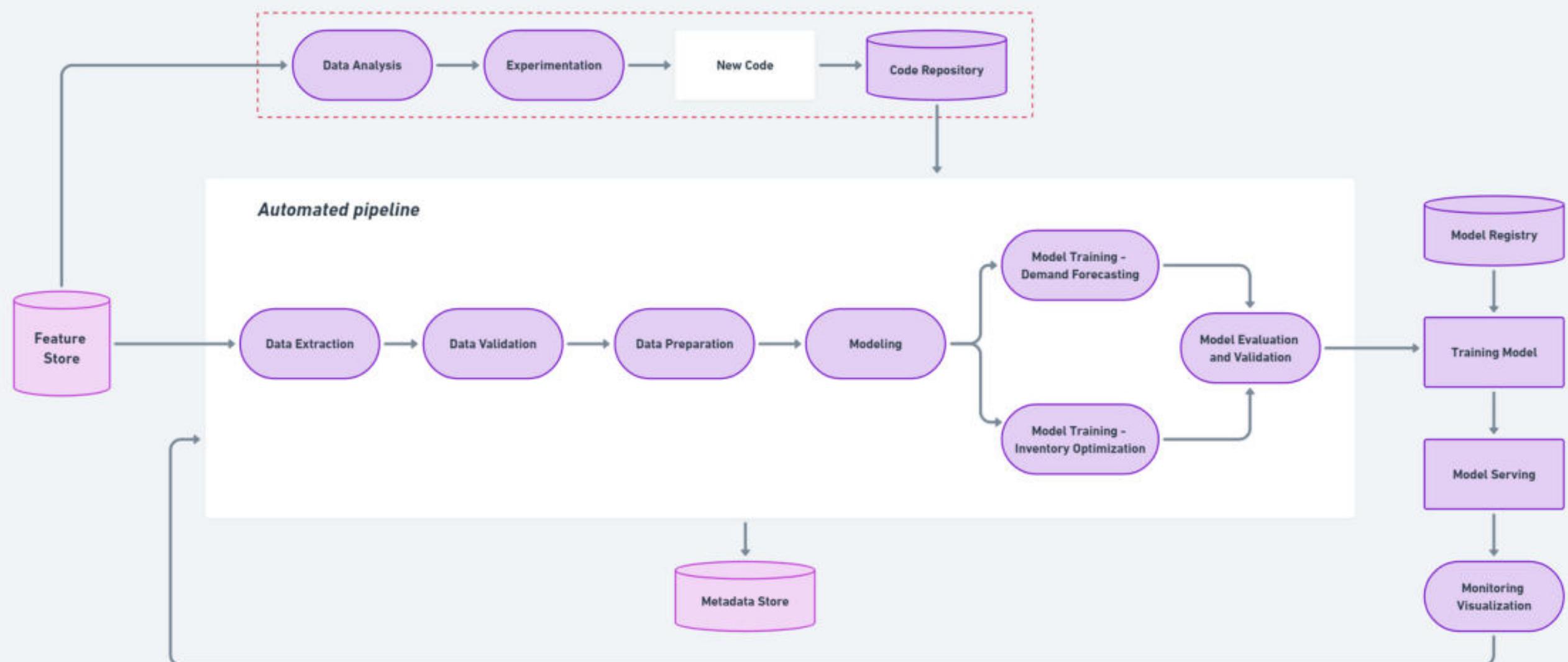


## INVENTORY OPTIMIZATION

The second challenge involves seamlessly integrating the developed demand prediction algorithm with an inventory optimization model. This integration aims to enhance decision-making by considering various factors for optimal inventory management.

# SOLUTION OVERVIEW

The suggested AI-based solution stands out for its creativity in addressing business objectives such as demand prediction and inventory optimization. The accompanying illustration highlights its important features.



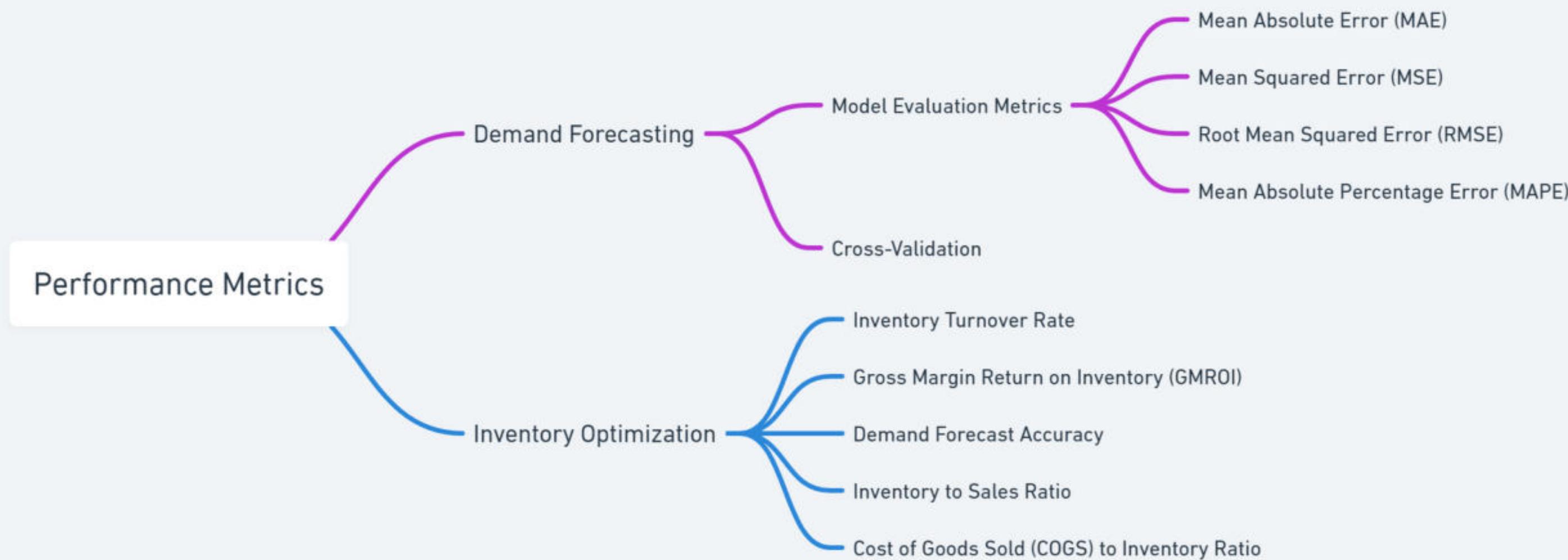
# METHODOLOGIES

Our project employs a robust set of methodologies, including:

- APIs and Integration Points for seamless data flow
- The Visualization and Reporting Layer for insightful analytics
- The Feedback Loop and Continuous Learning Mechanism for Adaptability
- The Real-Time Data Updating Component for timely information, an Inventory Optimization Module
- The Time Series Forecasting Module, and a Data Ingestion Layer for smooth data integration.

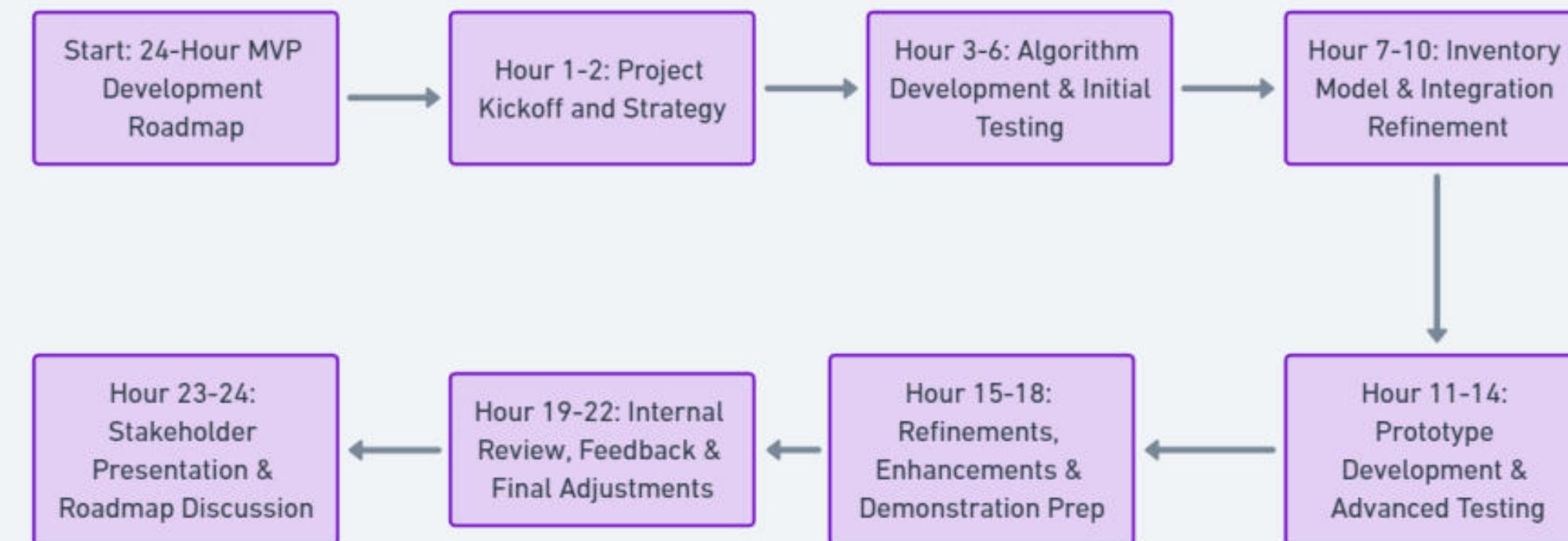


# PERFORMANCE METRICS



# TIMELINE ROADMAP

*TO BE SUITABLE FOR THE 24-HOUR COMPETITION, WE WERE FORCED TO ELIMINATE SECONDARY METHODS AND FOCUS ON TWO MAIN PROBLEMS: DEMAND FORECASTING AND INVENTORY OPTIMIZATION.*



**IF SEVERAL MODULES ARE PREPARED IN ADVANCE, WE CAN COMPLETE EVERYTHING PROPOSED**

# CONCLUSION



# INVENTORY OPTIMIZATION BASED ON DEMAND PREDICTION

## 1. Introduction

In today's volatile business environment, efficient supply chain management is critical for meeting client needs while maximizing operating efficiency. To achieve this, a comprehensive analysis of internal and external factors affecting the supply infrastructure is essential. Our proposal suggests leveraging advanced analytics and machine learning algorithms to analyze large datasets and identify patterns and correlations. This approach aims to help planners save resources and provide more accurate future demand predictions, addressing issues for a more efficient supply chain operation.

The primary goal is to accurately predict customer demand and optimize inventory levels, reducing stockouts, minimizing delivery times, and ensuring product availability. This customer-centric supply chain approach aims to deliver the right product, at the right time, in the right quantity, and at the right location, enhancing customer satisfaction and increasing revenue.

In detail, our demand forecasting involves proposing trends of products in high demand at a specific future time. This forecast is derived from a comprehensive analysis of historical sales data, market trends, customer behavior, product attributes, and other relevant factors. Equipped with this in-depth information, demand planners can formulate specific strategies for future sales volumes, improving financial planning and foresight.

Alongside demand forecasting, inventory optimization is crucial. This challenge revolves around the complex balance of maintaining sufficient inventory to meet customer demand while avoiding excess stock, which can lead to increased costs and financial difficulties. We integrate demand forecasts to suggest appropriate product quantities, keeping inventory levels low and providing enough for market demand. Additionally, we offer a comprehensive overview of inventory status, enabling businesses to optimize warehouse costs and enhance overall operations.

By combining advanced analytics and machine learning for demand forecasting and inventory optimization, we aim to elevate supply chain capabilities, ensuring a responsive, cost-effective, and customer-focused operation.

## 2. Problem Statement



Figure 1: Overview of the inventory optimization based on demand prediction

The problem or challenge that the Minimum Viable Product (MVP) seeks to address can be summarized in two main components:



Figure 2: Overview of the demand prediction and inventory optimization

**Demand Prediction Algorithm Development:** The first aspect involves the development of a demand prediction algorithm. The challenge is to create a reliable algorithm that can forecast future demand based on historical business data provided by the organizing

committee. This algorithm should take into account various factors, such as seasonality, trends, and any other relevant patterns present in the data. The goal is to provide accurate predictions that can guide decision-making related to inventory and supply chain management.

***Integration with the Inventory Optimization Model:*** The second component of the challenge is to integrate the developed demand prediction algorithm with an inventory optimization model. This integration should enable the optimization model to make informed decisions by considering multiple factors, including:

- Costs of unavailability: Assess the costs associated with not having sufficient inventory to meet demand.
- Resupply costs: Consider the expenses associated with replenishing inventory.
- Inventory costs: Account for the carrying costs and depreciation associated with holding inventory.
- Warehousing costs: Factor in the expenses related to storing inventory in warehouses.

The objective is to create a comprehensive inventory optimization model that takes into consideration the predicted demand, cost factors, and real-time data. This model should provide recommendations on inventory levels, resupply timings, and other relevant parameters to enhance overall business performance.

The pain points and inefficiencies associated with the described problem include:

***Inaccurate Demand Forecasting:*** Without a reliable demand prediction algorithm, businesses may face challenges in accurately anticipating customer demand. This can lead to overstocking or understocking of inventory, both of which have financial implications. Overstocking ties up capital and incurs holding costs, while understocking can result in lost sales opportunities and customer dissatisfaction.

***Suboptimal Inventory Management:*** In the absence of an integrated inventory optimization model, businesses may struggle with suboptimal inventory management. This includes challenges in determining the right reorder points, reorder quantities, and optimal stocking levels. Poor inventory management can lead to increased carrying costs, stockouts, and the need for expedited resupply, all of which can negatively impact the bottom line.

***High Costs of Unavailability:*** When inventory levels are not aligned with demand, there is a risk of stockouts. The costs associated with unavailability, such as lost sales, potential customer churn, and damage to the brand reputation, can be significant. Businesses need a solution that minimizes the impact of stockouts and optimizes the balance between inventory costs and the costs of unavailability.

***Inefficient Use of Resources:*** Without a data-driven approach to inventory optimization, businesses may allocate resources inefficiently. This includes tying up working capital in excess inventory, utilizing warehouse space ineffectively, and incurring unnecessary resupply costs. An integrated solution aims to optimize the use of resources, ensuring a balance between service levels and cost-effectiveness.

***Lack of Adaptability to Real-Time Changes:*** Traditional inventory management approaches may not adapt well to real-time changes in demand patterns or market conditions. Rapid shifts in customer behavior, unexpected events, or seasonality can significantly impact inventory requirements. A solution that incorporates real-time data allows businesses to adapt quickly to changes and make informed, timely decisions.

***Difficulty in Demonstrating Business Performance:*** Without a unified system that combines demand prediction and inventory optimization, businesses may find it challenging to demonstrate improved performance. The lack of a clear link between predictive insights and operational decisions can hinder the ability to showcase the positive impact on key performance indicators (KPIs) such as inventory turnover, customer satisfaction, and overall profitability.

In periods of economic downturns, the ability to forecast trends accurately and optimize inventory emerges as a critical challenge for businesses. The following highlights key benefits that forecasting and optimization can yield in challenging economic conditions:

***Cost Reduction:*** Accurate trend prediction enables businesses to avoid unnecessary procurement decisions, mitigating the risk of tying up capital for slow-moving products. Inventory optimization contributes to minimizing storage costs, thereby preserving working capital.

**Enhanced Flexibility:** Businesses that can precisely predict and optimize inventory demonstrate increased flexibility in adapting to market fluctuations. This heightened adaptability allows for swift adjustments to changing needs and shopping trends.

**Mitigation of Dead Stock Risk:** Accurate forecasting significantly reduces the risk of dead stock, encompassing unsold inventory or items sold at substantial discounts. Optimization ensures that inventory levels align with actual demand, minimizing the chances of excess or obsolete stock.

**Flexible Business Strategies:** Leveraging predictive analytics and optimization, businesses can formulate flexible strategies. This involves focusing on high-potential products or services and strengthening customer outreach efforts based on anticipated trends.

**Time and Energy Savings:** The adoption of prediction and optimization technologies diminishes the need for manual interventions and decisions based on intuition. This streamlined process saves valuable time and energy, allowing employees to concentrate on more strategic tasks.

**Effective Response to Economic Challenges:** The ability to predict and optimize inventory positions businesses to effectively navigate economic challenges such as competitive discounts, shifts in customer demand, and market fluctuations. This proactive approach contributes to better resilience in the face of economic uncertainties.

### 3. Solution Overview

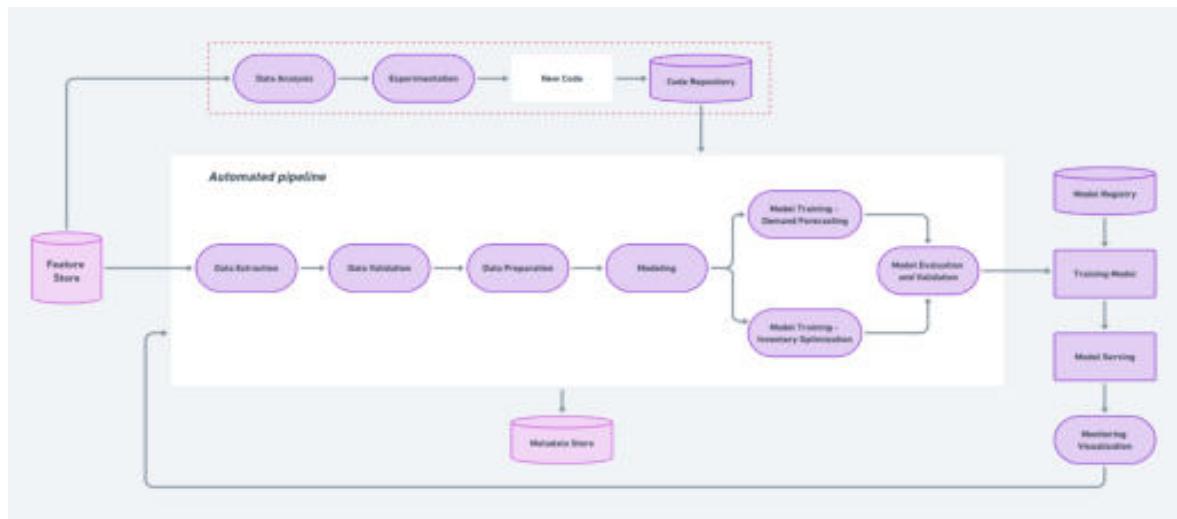


Figure 3: Solution overview

The proposed AI-based solution stands out for its innovation, bringing a novel approach to addressing business needs in demand prediction and inventory optimization. The key aspects of its innovation can be highlighted as follows:

***Data Processing and Analysis:*** Employ advanced data processing and analysis techniques to gain a comprehensive understanding of the business. This involves collecting and cleaning historical business data to establish a robust foundation for AI-driven insights.

***Develop machine learning algorithms and integrate time series models:*** Apply and develop machine learning algorithms, especially combining time series models to predict demand. Incorporating time series models for demand forecasting represents an advanced approach. By leveraging temporal patterns inherent in historical data, this solution improves the accuracy of demand forecasts. This integration allows the system to dynamically adapt to changing trends over time, providing more accurate and nuanced predictions.

***Holistic Approach to Inventory Management:*** The solution goes beyond conventional inventory management by integrating demand prediction with an optimization model. This holistic approach considers multiple factors, including costs of unavailability, resupply expenses, and various inventory-related costs. This comprehensive model ensures that businesses not only predict demand accurately but also optimize their inventory levels to minimize costs effectively.

***Real-Time Adaptive Decision-Making:*** The real-time decision-making capability sets this solution apart. By continuously updating predictive models with the latest data, the system enables businesses to make adaptive decisions on the fly. This responsiveness to real-time changes in market conditions, customer behavior, and other variables ensures that the business remains agile and resilient in the face of uncertainties.

***Automated Data Processing and Analysis:*** The solution employs advanced data processing and analysis techniques, automating tasks that traditionally required significant manual effort. This automation not only saves time but also reduces the risk of errors, allowing businesses to focus on strategic tasks rather than routine data processing.

***Feedback Loop for Continuous Improvement:*** The establishment of a feedback loop for continuous improvement is a key innovative feature. By monitoring the performance of the AI-driven models and incorporating feedback, the solution iteratively enhances its

accuracy and effectiveness over time. This adaptive learning mechanism ensures that the system evolves and remains effective in dynamic business environments.

**Visualization and Reporting for Actionable Insights:** The development of visualization tools and reporting mechanisms adds a layer of innovation. It empowers stakeholders with clear, actionable insights derived from AI-driven analysis. This user-friendly interface facilitates informed decision-making at various levels within the organization, promoting transparency and collaboration.

**Cost-Effective and Resource-Efficient:** By optimizing inventory levels and minimizing unnecessary costs, the solution proves to be cost-effective and resource-efficient. It addresses the business need for financial prudence, ensuring that capital is strategically allocated and not tied up in excess inventory or lost due to stockouts.

#### 4. Methodologies

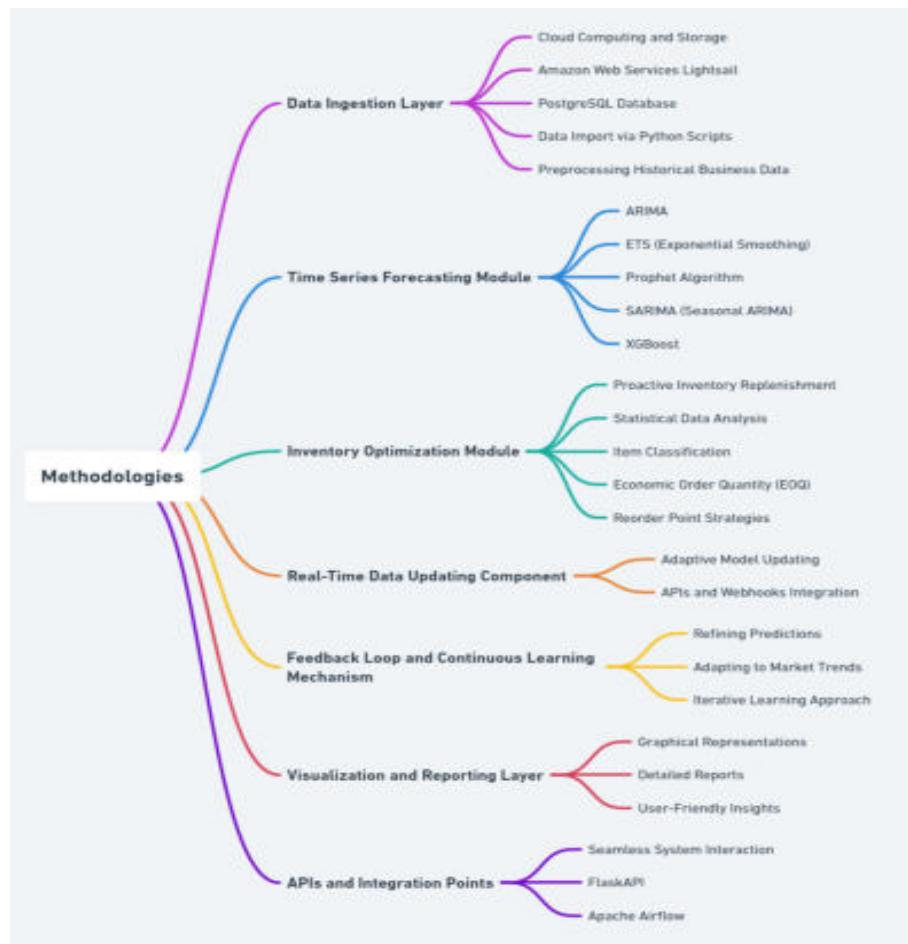


Figure 4: Methodologies

The AI model architecture is designed to seamlessly integrate time series forecasting and inventory optimization, providing a comprehensive solution for businesses. The key components, layers, and modules of the model are outlined below:

**Data Ingestion Layer:** With the rapid development of technology, particularly in cloud computing, cloud storage, and the provision of an increasing number of server and storage services, individual users and businesses now have numerous options for deploying applications and storing data more efficiently. Notable cloud service providers include Google with Google Cloud Platform, Microsoft with Microsoft Azure, and Amazon with Amazon Web Services. The presence of multiple competitive service providers offers users a wide range of choices at reasonable prices.

In addressing this challenge, our team opted for the Amazon Web Services Lightsail service to create a database. The service offers various databases, and our team specifically chose the PostgreSQL database. Using the data files provided by the Organizing Committee, the team populated the created database with data to support future activities such as querying, visualization, and providing data for building machine learning models. The data import step is executed through scripts written in the Python programming language, utilizing necessary libraries such as pandas and psycopg2.

This layer is responsible for collecting and preprocessing historical business data, including sales records, inventory levels, and relevant external factors. It ensures that the data is clean, formatted, and ready for analysis.

**Time Series Forecasting Module:** The Forecasting Module for Time Series Data in our system incorporates a variety of advanced algorithms, each specifically tailored to analyze and interpret different aspects of time series data. This module includes several key methodologies:

- **ARIMA (Autoregressive Integrated Moving Average):** This algorithm excels in identifying and capturing linear trends present in stationary time series data. It achieves this through a combination of autoregression (leveraging previous data points), differencing (to ensure data stationarity), and moving averages (to mitigate noise and fluctuations).
- **ETS (Exponential Smoothing):** The ETS approach, which encompasses models like Holt-Winters, is particularly effective in adapting to evolving data patterns. This

algorithm places progressively decreasing weights on past data, thereby accounting for error, trend, and seasonality.

- **Prophet Algorithm:** Specifically designed for datasets with daily observations, the Prophet algorithm is adept at managing data with irregular patterns, including missing values and holiday effects. Its flexibility makes it ideal for handling diverse and non-standard time series data.
- **SARIMA (Seasonal ARIMA):** Building upon the foundations of ARIMA, SARIMA introduces additional parameters to capture seasonal fluctuations in time series data. This extension enables a more nuanced analysis of data with inherent periodic patterns.
- **XGBoost:** Primarily known for its applications in classification and regression tasks, XGBoost has been ingeniously adapted for time series forecasting. By reformulating time series forecasting as a supervised learning challenge, XGBoost can uncover and leverage complex patterns within the data.

Each of these algorithms plays a pivotal role in our module, offering specialized capabilities to handle the diverse challenges presented by time series data analysis.

**Inventory Optimization Module:** This module makes use of a number of techniques to improve inventory management's precision and efficiency. When used in conjunction with the previously discussed demand forecasting model, this module makes proactive inventory replenishment possible. Through the analysis of statistical data and historical trends, this module enables businesses to decrease excess inventory and optimize inventory levels.

Furthermore, this module undergoes regular analysis, classifying items based on their significance and contribution to overall revenue. This classification supports prioritizing inventory management efforts, ensuring that essential items are adequately stocked while minimizing resources allocated to less important products.

Another key feature of this module is its application of economic order quantity (EOQ) and reorder point strategies. These strategies consider various factors, including the costs of ordering and holding inventory, as well as fluctuations in demand. This functionality is crucial in establishing the most effective order sizes and timing for reordering, which helps in avoiding both shortages and surpluses in inventory.

**Real-Time Data Updating Component:** Ensure the model remains adaptive by continuously updating it with real-time data. This component enables the system to adjust its predictions and optimize recommendations in response to dynamic changes in market conditions or business factors.

Provide APIs and webhooks to facilitate the integration of external systems. This approach allows for seamless communication and data exchange with other services requiring real-time updates.

**Feedback Loop and Continuous Learning Mechanism:** Through this ongoing process, we aim to refine and improve predictions, as well as continuously optimize strategies. Our model is designed to adapt persistently to real-world scenarios, enhancing its efficiency, staying attuned to market trends, and responding swiftly to changes in the market. This iterative approach to learning fosters a dynamic and adaptable system, thereby maximizing its practical effectiveness.

**Visualization and Reporting Layer:** The Visualization and Reporting Layer is essential for translating complex model outputs into understandable, user-friendly insights. It utilizes graphical representations and detailed reports to provide stakeholders with clear, actionable information. This facilitates informed decision-making by making data trends and patterns easily interpretable and accessible, thereby bridging the gap between advanced data analysis and practical business applications.

**APIs and Integration Points:** Facilitates integration with existing business systems and processes through APIs and integration points. This ensures seamless interaction with databases, external tools, or other software components:

- **FlaskAPI:** We leverage FlaskAPI for its robust framework, ideal for developing and serving APIs. Its simplicity and flexibility are key to crafting efficient API endpoints.
- **Apache Airflow:** Apache Airflow is our chosen tool for orchestrating and automating data and task flows. Its capability to schedule and trigger APIs efficiently guarantees the timely execution of essential processes.

## 5. Core Functionality

### ***Data Ingestion Layer:***

- Cloud Storage Integration: Implement functionalities to connect and store data on cloud platforms like Amazon Web Services Lightsail.
- Database Connectivity: Develop capabilities to connect to a PostgreSQL database for data storage and retrieval.
- Data Import Automation: Write Python scripts to automate the process of importing data.
- Data Preprocessing: Include functions for cleaning and preparing historical business data for analysis.

### ***Time Series Forecasting Module:***

- Forecasting Algorithms: Implement various statistical and machine learning algorithms such as ***ARIMA***, ***ETS***, ***Prophet***, ***SARIMA***, and ***XGBoost*** for time series forecasting.
- Model Training and Selection: Code the functionality to train these models on historical data and select the best-performing model.

### ***Inventory Optimization Module:***

- Inventory Analysis: Develop algorithms to analyze inventory levels using methods like Economic Order Quantity (EOQ) and Reorder Point Strategies.
- Replenishment Trigger: Create functions to trigger proactive inventory replenishment based on forecasted demand.

### ***Real-Time Data Updating Component:***

- Data Streaming Integration: Build connectors for real-time data streams using APIs and webhooks.
- Model Update Mechanism: Code the ability to adaptively update models based on incoming real-time data.

### ***Feedback Loop and Continuous Learning Mechanism:***

- Prediction Refinement: Incorporate features to refine predictions as more data is collected.
- Market Adaptation: Add functionality to adjust to market trends through an iterative learning approach.

### ***Visualization and Reporting Layer:***

- Data Visualization: Implement tools for graphical representations of data and forecasts.
- Report Generation: Develop capabilities for generating detailed, user-friendly reports.

### ***APIs and Integration Points:***

- API Development: Build a RESTful API using FlaskAPI for interaction with external systems.
- Workflow Automation: Integrate with Apache Airflow to manage and automate the workflow processes.

## **6. Performance Metrics**

### ***Demand Forecasting:***

- Model Evaluation Metrics: Key metrics to evaluate the model's performance include:
- Mean Absolute Error (MAE): Average of the absolute differences between forecasts and actual values.
- Mean Squared Error (MSE): Average of the squares of the differences between forecasts and actual values.
- Root Mean Squared Error (RMSE): Square root of MSE, commonly used because it is in the same units as the forecasted quantity.
- Mean Absolute Percentage Error (MAPE): Average of the absolute percentage errors, useful for comparing accuracy across different data scales.
- Cross-Validation: This involves dividing the data into training and testing sets to validate the model's performance. Time series cross-validation is different from traditional

### ***Inventory optimization:***

- Inventory Turnover Rate: Indicates how often the inventory is sold and replaced over a specific period. A higher turnover rate suggests efficient inventory management but can also lead to stockouts.
- Gross Margin Return on Inventory (GMROI): Assesses the profit return on the amount invested in inventory. A higher GMROI indicates more efficient use of investment in stock.
- Demand Forecast Accuracy: Measures how closely the inventory levels match the actual demand. High accuracy can lead to better stock levels and reduced costs.
- Inventory to Sales Ratio: Compares the amount of inventory kept in relation to the sales volume. This ratio helps in understanding if the inventory levels are aligned with sales trends.
- Cost of Goods Sold (COGS) to Inventory Ratio: This ratio assesses the relationship between the cost of goods sold and the average inventory level, providing insights into inventory efficiency.

## **7. Timeline and Roadmap**

To be suitable for the 24-hour competition, we were forced to eliminate secondary methods and focus on two main problems: demand forecasting and inventory optimization.

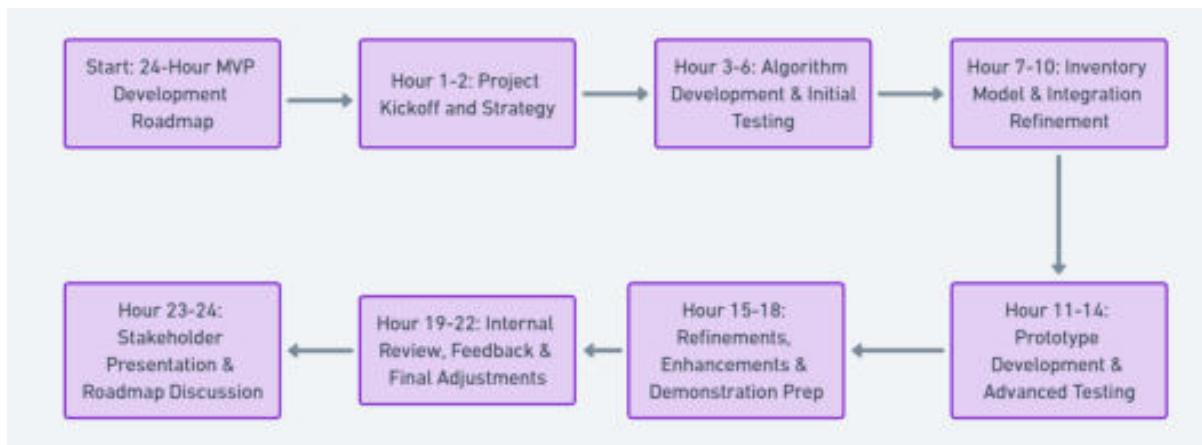


Figure 5: Timeline and roadmap

## 8. Conclusion

Our MVP for Inventory Optimization based on Demand Prediction harnesses AI to revolutionize supply chain management. This solution:

- Enhances Accuracy: Precisely predicts customer demand using advanced machine learning, reducing stock imbalances.
- Optimizes Inventory: Balances stock levels effectively, minimizing costs and maximizing efficiency.
- Adapts in Real-Time: Quickly responds to market changes, ensuring resilience and agility in supply chain operations.
- Improves Cost-Effectiveness: Reduces unnecessary expenses, optimizing resource use.
- Facilitates Informed Decisions: Transforms complex data into actionable insights for better strategic planning.
- Future-Proofs Businesses: Equips companies with cutting-edge tools to stay competitive and adaptable.

Implementing the MVP presents certain challenges, particularly regarding time and resources:

- Time-Intensive Development: The creation of sophisticated machine learning models and integration of advanced analytics demand considerable time for development, testing, and refinement.
- Data Collection and Preparation: Gathering and preprocessing extensive historical data for model training is a resource-intensive task, requiring significant effort and time.
- Technical Expertise Requirement: Implementing AI and machine learning solutions necessitates specialized skills and knowledge, which might involve training existing staff or hiring new talent.
- System Integration and Compatibility: Integrating the new AI system with existing inventory and supply chain management systems can be complex, requiring additional time and resources for seamless integration.
- Validation and Testing: Ensuring the reliability and accuracy of the predictive models through comprehensive testing and validation is critical but time-consuming.

- Continuous Improvement and Maintenance: Post-implementation, the system requires ongoing maintenance and updates to adapt to changing market conditions and business needs, demanding continuous investment of time and resources.
- Resource Allocation for Scalability: As the business grows, scaling the AI system to handle increased data volume and complexity might require additional resources and infrastructure upgrades.