NITIE- It’s engagement to transform the business operations with Analytics

EXECUTIVE SUMMARY

National Institute of Industrial Engineering (NITIE) is considered one of the leading academic and research institutes for its expertise in operations and supply chain management. NITIE has acted as a pioneer in building an Industry-Academia Partnership that fosters R&D and innovation in pursuit of timely themes in applications and infrastructure, including, AI and machine learning, operating systems, supply chain management, logistics handling, networking, Big Data, security, storage, and data analytics.

This report envisages all the research collaboration outcomes with various reputed industries and the application of digitization in providing implementable solutions. The industries are related to Port Authorities, Famous Airlines Companies, Cargo handling giants/Freight forwarding companies, Steel Industries, and Consulting companies quite active in the domain of logistics and supply chain management.

All this research work has been carried out under the esteemed supervision of our Director Prof. Manoj Kumar Tiwari, guided by the core faculty members of NITIE, and executed by the research scholars, students of NITIE, and interns.

NITIE's Engagement with different Sectors

1. Demand Planning and Predictions
2. Fashion product sales prediction
3. Inventory and Warehousing
4. Predicting consumption Pattern of the steel Industry
5. Air cargo handling and Airlines Operation Management
6. Shipping and Port Logistics
7. Resiliency in Supply chain
8. Human Resource Development

CONTENTS

Prediction and Analysis of Seasonal Dynamic Steel Consumption

1 Data Analysis and Pre-processing

Understanding the data distribution and structuring it based on the observations

2 Feature Engineering and Algorithm Selection

Introducing lag features including rolling mean, consumption trends etc, to integrate temporal features.

3 Results

Finding results and outputs of our trained machine learning model

Objective

To predict the amount of steel consumption required in the next 1 month interval.

•Reduce lead time by allowing pre-ordering
•Reduce material wastage
•Allows room for storage space

Inputs

- Data consists of daily consumption 35 steel types from April 2014 to March 2019
- Each metal represented by a material code can be divided into material type, section and material number
- Converting date into month part, month and year, along with continuous time series

Procedure

•Model trained on daily data
•Model draws out the hidden trends and cycles
•Extends the Dataset
•Results are aggregated on a monthly basis

Algorithms used:

- Random Forest
- Light Gradient Boosting Machine
- eXtreme Gradient Boosting
- Categorical Boosting

Output

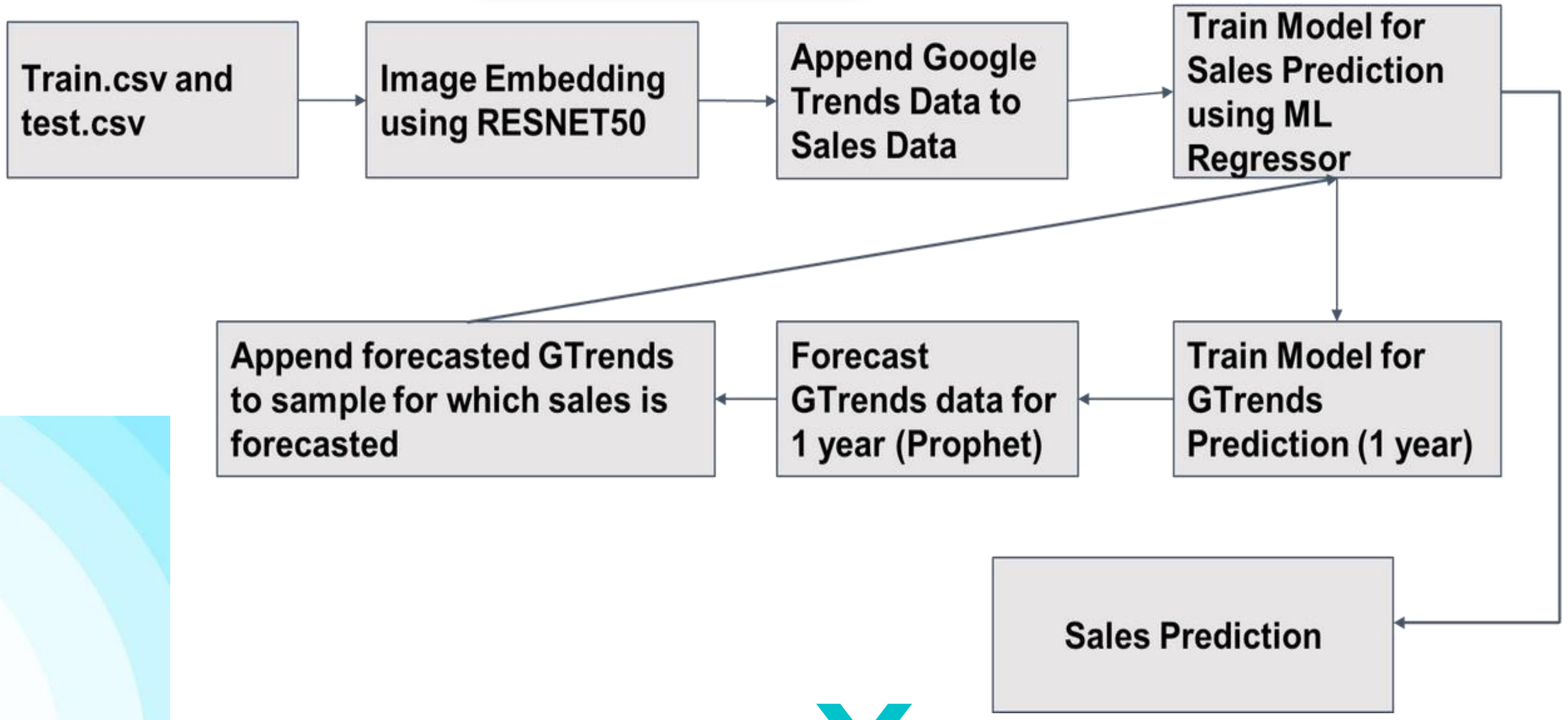
- We have forecasted specific steel requirements for the coming month so that they can be added to the inventory before orders come in.
- This will significantly reduce the lead time by removing the time taken due to the material acquirement period.
- Inventory space is also saved by allocation to the relevant material type, thus reducing wastage of space.
- Furthermore, integrating additional methods such as safety stock reduces any backlog of material

Multimodal Forecasting of New Fashion Product Sales with Image-based Google Trends

Features

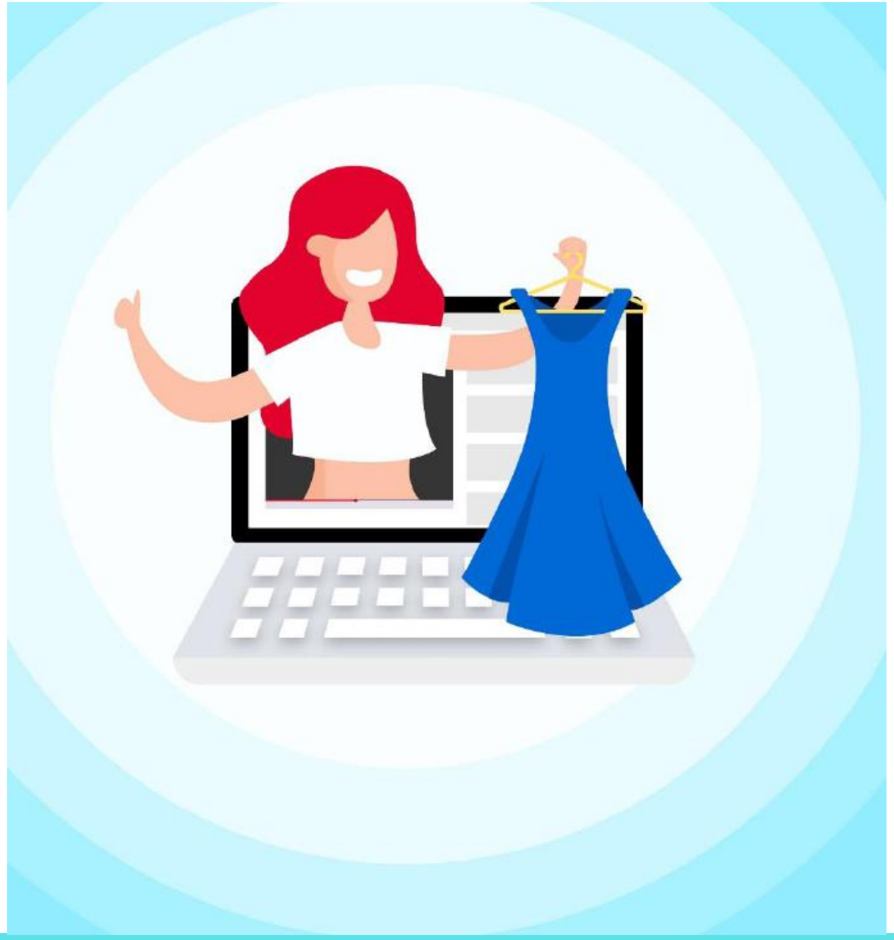
- Image
- Textual metadata
- Sales after the first release date
- Google Trends
- category, color and fabric
- Release Date

Steps Involved :



ALGORITHMS USED

- Prophet
- Neural Network
- Support Vector Regression
- XGBoost Regression
- LightGBM



Sales Forecasting for one year:

1. Gtrend-integrated sales data is used for sales forecasting.
2. Multi - output LightGBM regressor is used for sales forecasting.
3. Forecasted Gtrends data is used for sales forecasting, which was output of time series forecasting of Prophet model.

Application of Advanced Deep Learning Algorithms for Sales Forecasting

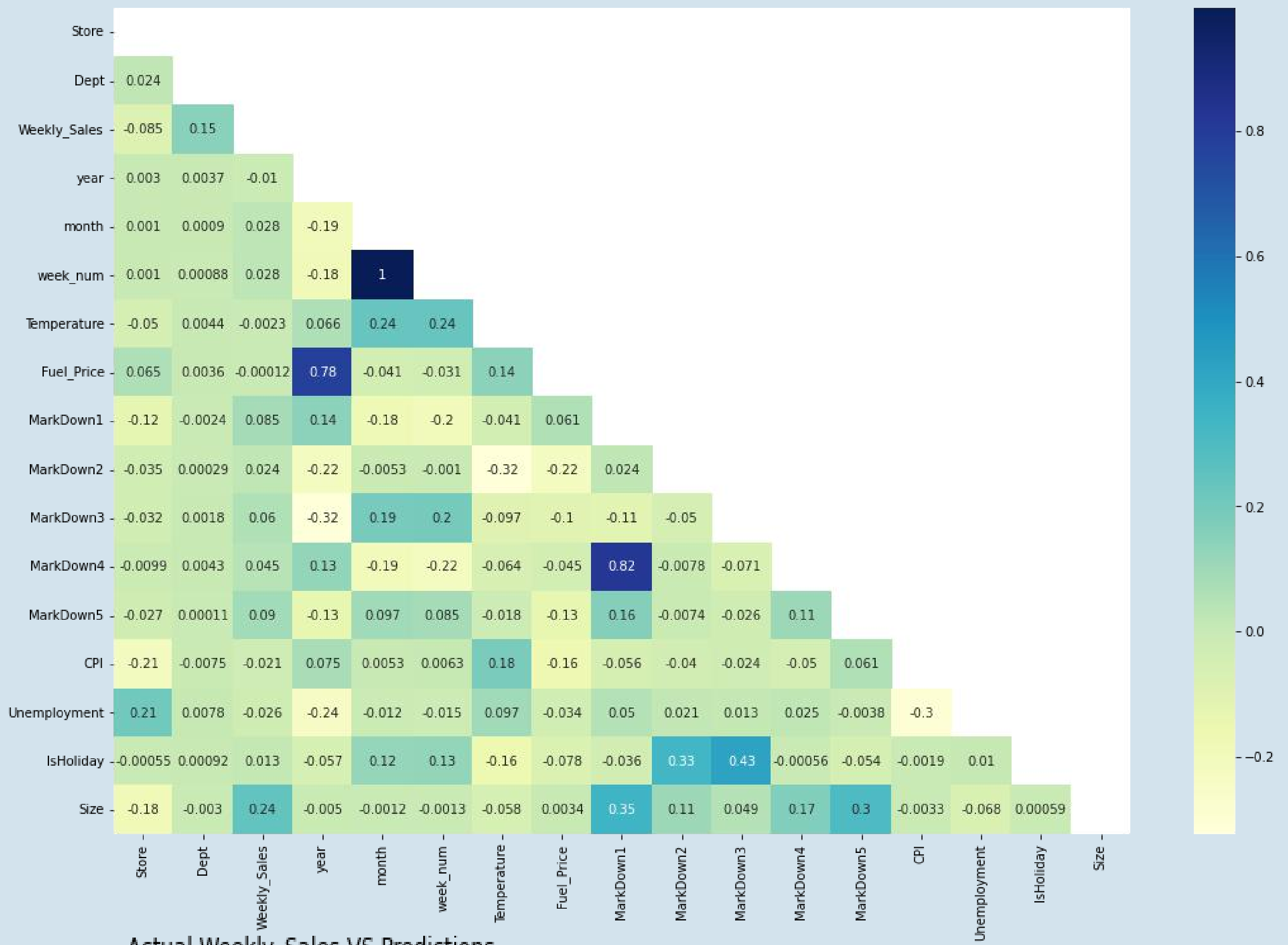
Sales forecasting helps businesses, especially those operating large chains of business networks to drive future revenue and development.

INPUT

- Data consists of Weekly Sales of 45 stores from February 2010 to November 2012.
- Also dataset contains 81 unique departments in the stores, three types of stores, promotional activities, holidays.

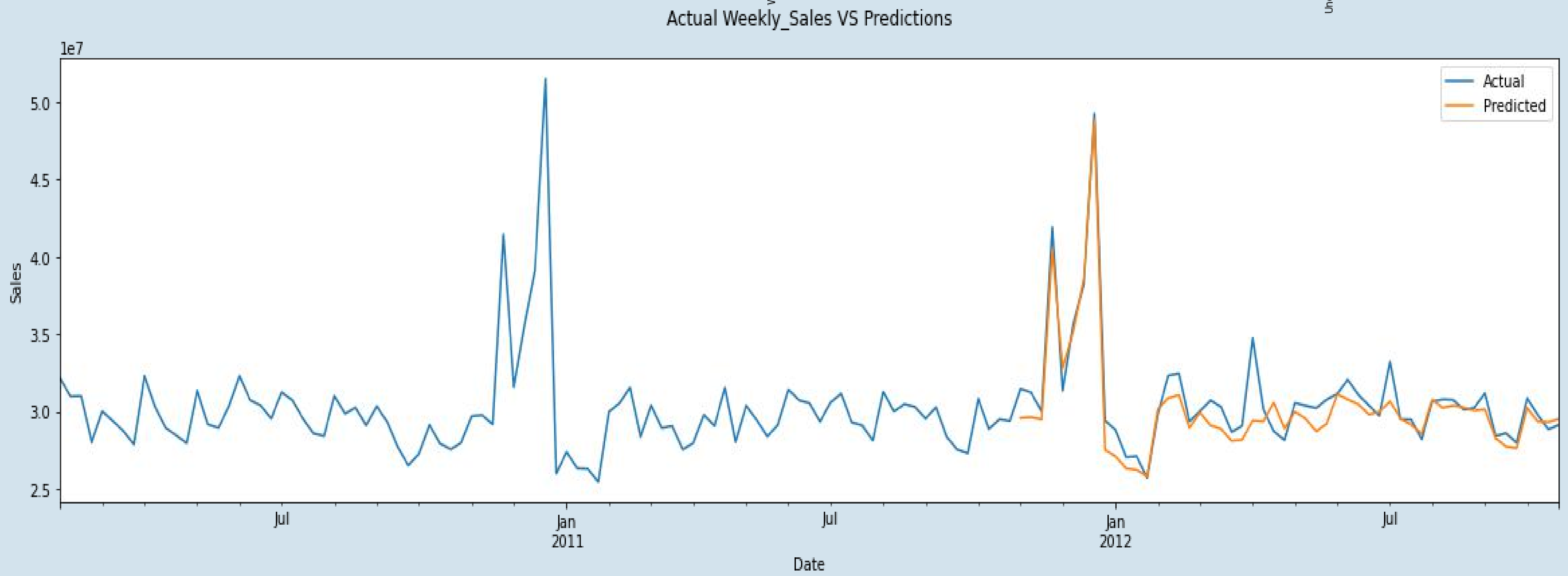
OBJECTIVE

Accurate and efficient sales forecasting of each store for the next 3 months.



STEPS INVOLVED

- Data Analysis
- Data Pre-processing
- Feature Engineering
- Algorithm Used
  - PARALLEL CNN-LSTM
  - PARALLEL CNN-GRU



Material Consumption Prediction of a Power Transmission Equipment Manufacturer

OBJECTIVE

Accurate and efficient raw material consumption prediction of each Product ID (PCN) for the next three months.

Data Preprocessing

- Expand the given datasets in Time Series data format
- Extract features as ‘Year’ and ‘Month’
- Group by ‘PCN’ and ‘Date’
- Fill the missing value in ‘Consumption’ by Interpolation
- Outliers are handled by IQR using boxplot

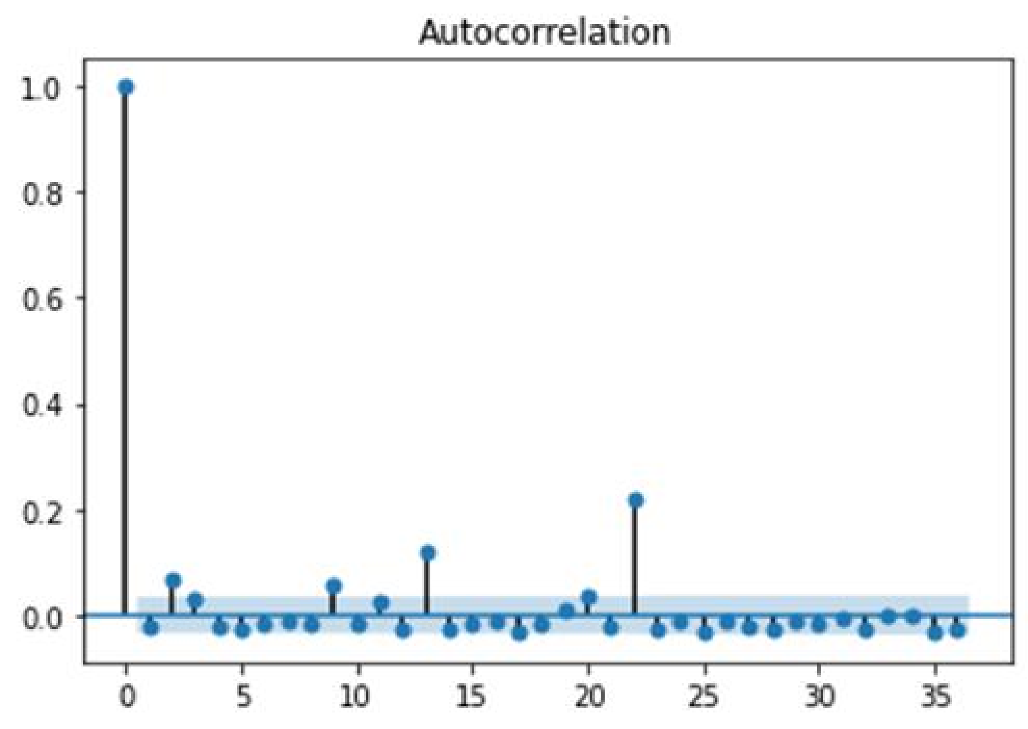
Algorithm Used: Hybrid KNN and LightGBM

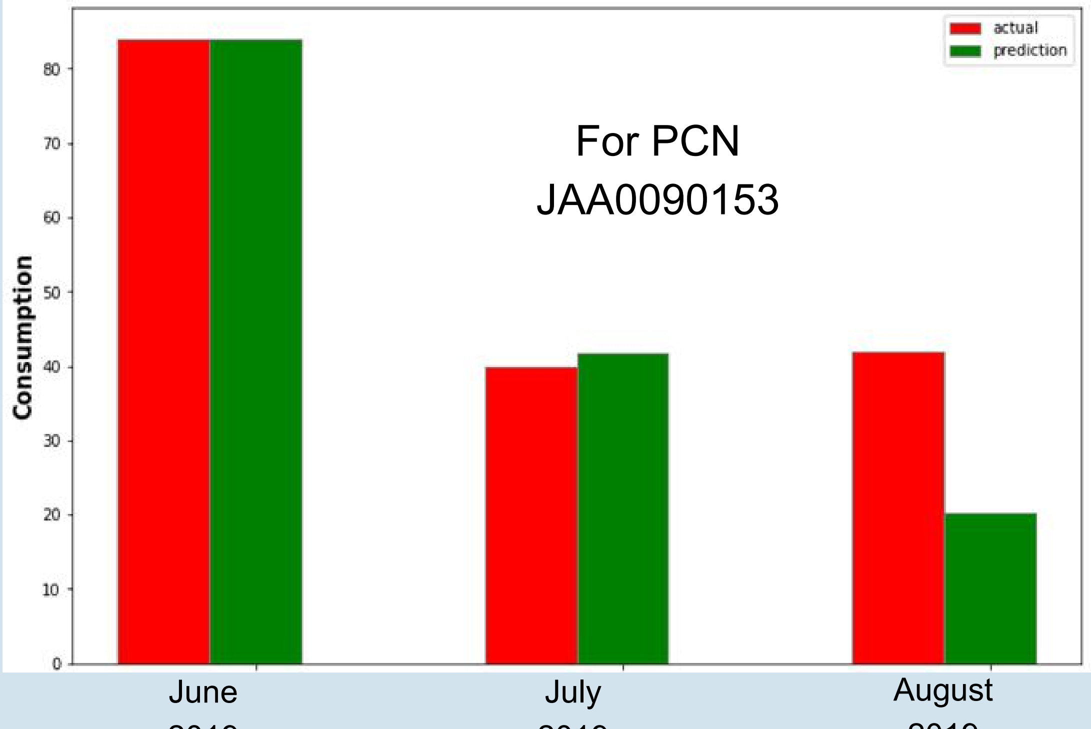
INPUT

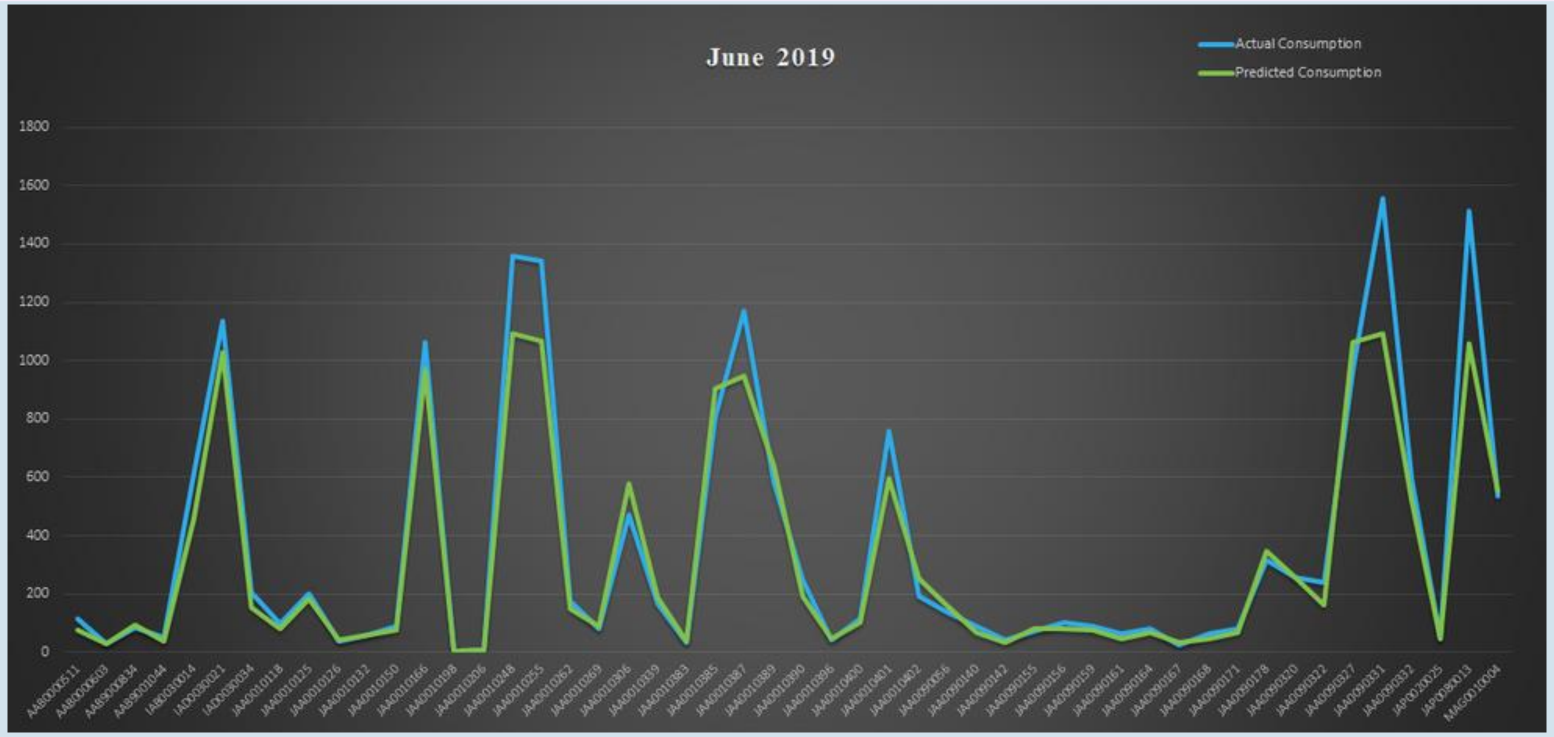
Data consists of monthly Consumption of 290 unique products from April 2018 to August 2019.

Feature Extraction

- Based on the variance of the consumption per month, lag is used to create feature
- Also, rolling mean is used on consumption for feature creation
- Exponential rolling mean is used for feature creation
- Use logarithm on consumption to reduce huge variation
- Normalize the data using mean and Standard deviation



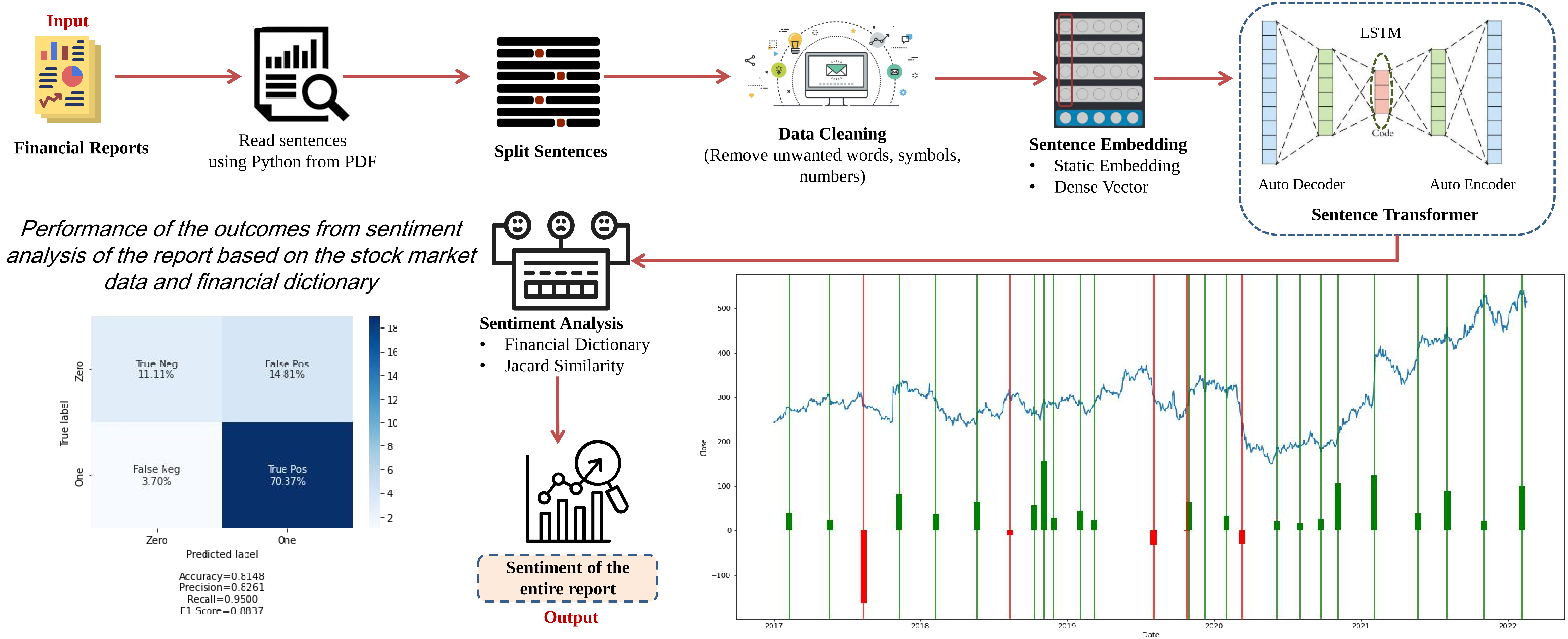




Sentiment Analysis of Financial Reports

OBJECTIVE: Determine the sentiment strength from the financial reports generated by global leaders in financial services for decision making.

INPUT: Financial reports of 6 banks from 5 financial services from April 2017 to March 2022



CARTON SET OPTIMISATION

Problem Addressed

Given a particular a set of orders to be packed in a warehouse. Each order contains 5-20 items of different shapes and size. Need to find an optimal carton set to fit all the orders efficiently.

Methodology

Input is N orders from different customers

Heuristic to pack each order

Optimization: Select only a few cartons and fit all the orders while reducing the shipping costs

N orders → Heuristic → k-means Clustering

ORDER CUBING

- **Input:** A set of *N* orders
- **Algorithm:** Takes in an order and fits it to a carton optimally
- **Output:** A set of *N* cartons

Why: Each order is fitted into the best carton possible to reduce space wastage

Solution Impact

An optimal carton set can lead to a better inventory space utilization, lower carbon foot print and an overall reduction in expenses.

Environmental Benefit: Annual Corrugate Comparison

Current Carton Set	Carton Optimal Set	Carton Reduction (%)	Annual trees saved	Annual CO2 emission reduced
41.2 M ft²	39.5 M ft²	4.1 %	1401	28,441 kg

Modelling and Analysis of Air cargo Cost Minimisation

OBJECTIVES

- Minimize total shipping cost
- Minimize total time consumed
- Minimize total Fuel Consumption

→

- Fixed operation cost
- Total Inventory Cost
- Loading and unloading cost
- Holding cost
- Fuel consumption cost
- Cost of Carbon emission

INPUT PARAMETERS

01 NUMBER OF SHIPMENTS

Number and type of shipments mostly eCommerce and poultry items having low shelf life

02 NUMBER OF ORIGIN

Air freight rates , Origin charges

03 NUMBER OF DESTINATION

Cargo handling charges, Sustainable operations,

04 NUMBER OF SHIPPING AGENTS

Cargo Integration, consolidation and deconsolidation

SOLUTION APPROACH

- IBM ILOG CPLEX
- Particle Swarm Optimisation (PSO)
- GLN PSO

Prediction of delay to minimize air cargo transport risk

01 Data Collection

Real time data from Cargo 2000- the bUsiness process of a freight forwarding company

The amount of data is often a crucial Factor governing the accuracy

02 Data Cleaning

- Pre-Processing the Data.
- Handling Missing values
- Removing Outliers
- Getting a subset of clean and structured data

03 Feature Engineering

- Understanding Data
- Extracting most dominant features responsible for delay
- Extracting Features:
- Random Forest

04 Algorithms

- Decision Trees
- Random Forest
- XgBoost
- CatBoost
- Neural Networks
- ANN
- Ensemble Learning using Bagging and Stacking

05 Results and Recommendations

- Visualize the prediction
- Planning
- Business Process Monitoring
- Inventory Management
- Capacity Planning
- Servicing Schedule

First mile and Last mile Optimization

GEOCODING ADDRESSES

Daily Tonnage Movement

Route Optimization

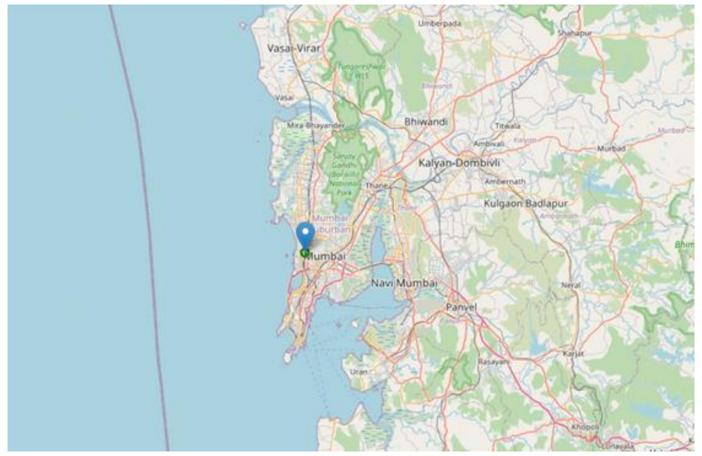
Optimize the vehicle route by minimizing the total distance traveled
Perform Deliveries and Pickups simultaneously with the same vehicle

OBJECTIVE

Minimize total distance covered

To find the optimal route for each vehicle, whose route starts with a GDW and ends with a GDW.

Step -1: GEOCoding Addresses



- Location string given as input
- Results derived using Geopy
- Visualization using Folium

Step 3 - Route Optimization with Simultaneous Pickup and Delivery

INPUT PARAMETERS

01 VEHICLE CAPACITY

02 AMUNT OF PICK UP GOODS ON BOARD

03 AMOUNT OF DELIVERY GOODS ON BOARD

04 NUMBER OFVEHICLES

Step 2 - Daily Tonnage Movement

Extracting the Daily Tonnage Movement between each customer location and GDW.

- Delivery and Pickup Counts
- Delivery Tonnage per GDW
- Pickup Tonnage per GDW
- Average Weight of Shipment:
- GDW Wise AVG Tonnage Delivered and Pick up

SOLUTION APPROACH

- GUROBI solver

Airline Management and Operations

7. Cockpit Crew Scheduling Problem
8. "Tail Mapping" – Aircraft Route Allocation
9. Aircraft Maintenance Scheduling
10. Ground Staff & Security Rostering
11. Airport's Baggage Handling Systems and Fault Detections

All Operational plans are driven by the Airline's Network Plan & Commercial Aviation Policies

Cockpit Crew Scheduling Problem

Overview: Using the Approved Schedule Available for the Flight Legs, an Optimization Program is Designed to Generate Optimal Pairings

Objective

Selection of minimum no. PAIRINGS required to cover all flight legs at least once, with user-defined or as few layovers and deadheads as possible

Inputs

- Aircrafts
- Legs
- Timing
- Frequency

Depth First Approach

•Enumeration of Duties & Pairings Combinations

Linear Optimisation

•Run Optimization for Selected Scenarios

•Carried out in Python
•8GB RAM Windows 8 System

Output

Details of Optimized Pairings obtained as Output in an Excel Sheet

"Tail Mapping" – Aircraft Route Allocation

Tail Mapping or Tail Assignment is the problem of assigning specific aircraft to flights, producing a fully operational, robust schedule which fulfills operational constraints, while minimizing a cost function.

Objective

- Optimization of route for each aircraft
- Satisfy the maintenance needs of aircrafts
- Maintain the stipulated gap between two consecutive legs
- Consideration of crew pairing while optimizing the routes
- Perform legs without any delay
- Better utilization of aircrafts
- Allocation of aircrafts to routes based on performance factor
- Reduce variable cost

TAIL MAPPING TOOL

OPTIMIZATION MODEL

- Integer Programming Model
- Carried out in Python 3.7.7 64-bit, Spyder 4.1.4
- Total Solution time ~ 2 minutes

INPUT DATA FILES REQUIRED FOR OPTIMIZATION MODEL

- Legs data file (for the concerned day and the next day)
- Aircraft data file (for the concerned day and the next day)
- Fix Routes data file
- Restriction data file (for Restricted routes for each aircraft)
- Cost data file (for fuel cost data)

OUTPUT DATA FILES GENERATED FROM OPTIMIZATION MODEL

- Routing file with Minimum cost
- Routing file with More Ground Time
- Aircraft data generated (with Minimum cost)
- Aircraft data generated (with More Ground Time)
- Optimization Solution file
- Merged Legs file

AIRCRAFT MAINTENANCE SCHEDULING

AN OPTIMIZATION MODEL IS DEVELOPED TO FIND THE MINIMUM NUMBER OF CERTIFIED PERSONNEL REQUIRED AT EACH BASE FOR EACH AIRCRAFT.

SALIENT FEATURES:

- Single click solution developed using open-source software – python.
- The tool can be used to generate daily/weekly/monthly maintenance allocation schedule
- Manpower allocation at each base for both team A & team B is achieved with scope for buffer time
- Log data showcasing activity and aircraft wise distribution, also bench marked with solvers for reduced run time and improved accuracy

GROUND STAFF & SECURITY ROSTERING OF AIRLINES

An Optimization model is developed to find the minimum number of ground staff required at an airport base for security and customer services (checkin, boarding, etc.)

A python-based model is developed to cater to different roles of personnel and their inter-operability within roles and locations at the base during shifts

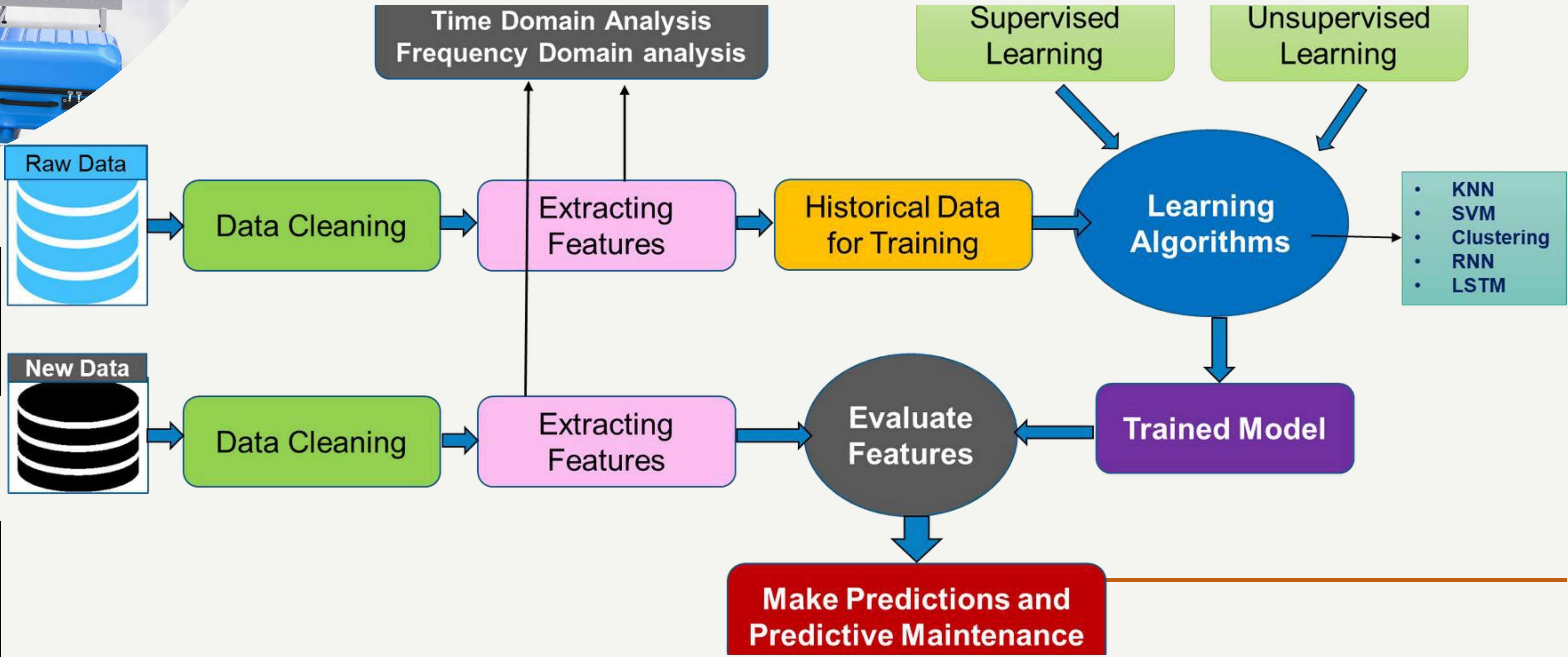
The tools can help in identifying minimum manpower required at the base as per the role and the schedule of arrivals and departures of flights of the airline

Duty rules such as days-off, employee transport and company guidelines are considered in the model

Airport's Baggage Handling Systems and Fault Detections

Airline oarganization's aim:

- **Minimum downtime**
- **Minimum maintenance costs**
- **Increase in the service level.**



Insight

- Random Forest algorithm has been utilized to make a real-time decision to monitored the equipment using a smartphone.

- Sensor installation is costly, but by predicting machine failure in an advanced company can minimize machine downtime, and labor hour, and increased in productivity.

Simultaneous Planning of Liner Ship Speed Optimization, Fleet Deployment, Scheduling and Cargo Allocation

OBJECTIVES

- Minimize total shipping cost →
  - Fixed operation cost
  - Berth occupancy charge
  - Loading and unloading cost
  - Transshipment handling and Holding cost
  - Fuel consumption cost
  - Cost of Carbon emission while sailing in the sea and operating at the ports
- Minimize total time consumed by the vessels to fulfill container shipment demands of each port

DECISIONS TAKEN

01 FLEET DEPLOYMENT DECISION

Number and type of required ships deployed on each route.

02 OPTIMAL SPEED DECISION

Sailing speed of ships on each leg of routes

03 SERVICE SCHEDULE DECISION

Timing when vessels arrive at each port of call on each route every week.

04 CARGO ALLOCATION DECISION WITH TRANSSHIPMENT

Flow of containerized cargo routed through services from their origin to destination

SOLUTION APPROACH

- Non-dominated Sorting Genetic Algorithm II (NSGA-II)
- Online Clustering-based Evolutionary Algorithm (OCEA)

Fuel Bunker Management Problem for Liner Shipping Networks

ASSUMPTIONS

- Different fuel pricing scenarios
- For each origin-destination, volume of container shipment demand (TEU per week) is fixed
- heterogeneous vessels
- Bunker consumption on each voyage leg is based on both the vessel speed and payload

OBJECTIVE

Maximize total profit =

Freight revenue - Container inventory cost - Bunkering cost (HFO) - Fixed cost of ships - MDO fuel cost at ports - Waiting cost for arriving early - Penalty cost for late arrival - Transshipped container handling cost - Transshipment holding cost - Loading and unloading cost - Carbon emission cost while sailing in the sea - Carbon emission cost while operating at the port.

Decisions taken

01 Bunkering decision

How much bunker fuel will be loaded

On which port of call the vessel loads fuel

02 Fleet deployment decision

Number and type of required ships deployed on each route.

03 Optimal speed decision

Sailing speed of ships on each leg of routes

03 Service schedule decision

Timing when vessels arrive at each port of call on each route every week.

04 Cargo allocation decision with transshipment

Flow of containerized cargo routed through services from their origin to destination

Solution Approach:

Bi-directional tuning heuristic- An iterative procedure to solve the model by dividing it in submodels.

Business Analysis – Turn Around Time

Turn Around Time

This is the total amount of time it takes for a port to finish its operations for one ship.
The lower this metric is, the faster a port can service more ships.
While there are many factors that can affect this metric, many uncontrollable, there should be no unnecessary delays to increase i

Factors affecting this are between:
-pre berthing
-departure time.
Each having its own downtimes sometimes outside of ports control

We look at each factor to understand:
Overall effect trends and hidden patterns.

Plan solutions for the port to improve operations and help reduce or at least minimise any increase in Turn Around Time

Decision Support Model for Optimizing Bulk Material Handling Operations

Berth Status

Ship Schedule

Input

Stockyard Status

Rake Schedule

Physical Parameters

- Manual shifting rate
- Mech. ship unloading rate
- Manual ship unloading rate
- Mechanized rake loading rate
- Manual rake loading rate

A Decision model to capture the complete dynamic aspects of port operation

Methodology

- Clean and format data to identify main factors. e.g. Total Tonnage, Net Volume, Birth Number, etc.
- Perform Exploratory Data Analysis to understand the overall distribution
- Check distribution and trends to identify problem areas and anomalous \occurrences, e.g. Specific weight segments for certain cargo
- Generated plans to combat these cases to reduce unnecessary increase in time
- Programmed a model using various ML/AI algos to have a benchmark to help maintain similar levels of performance and accountability

Output

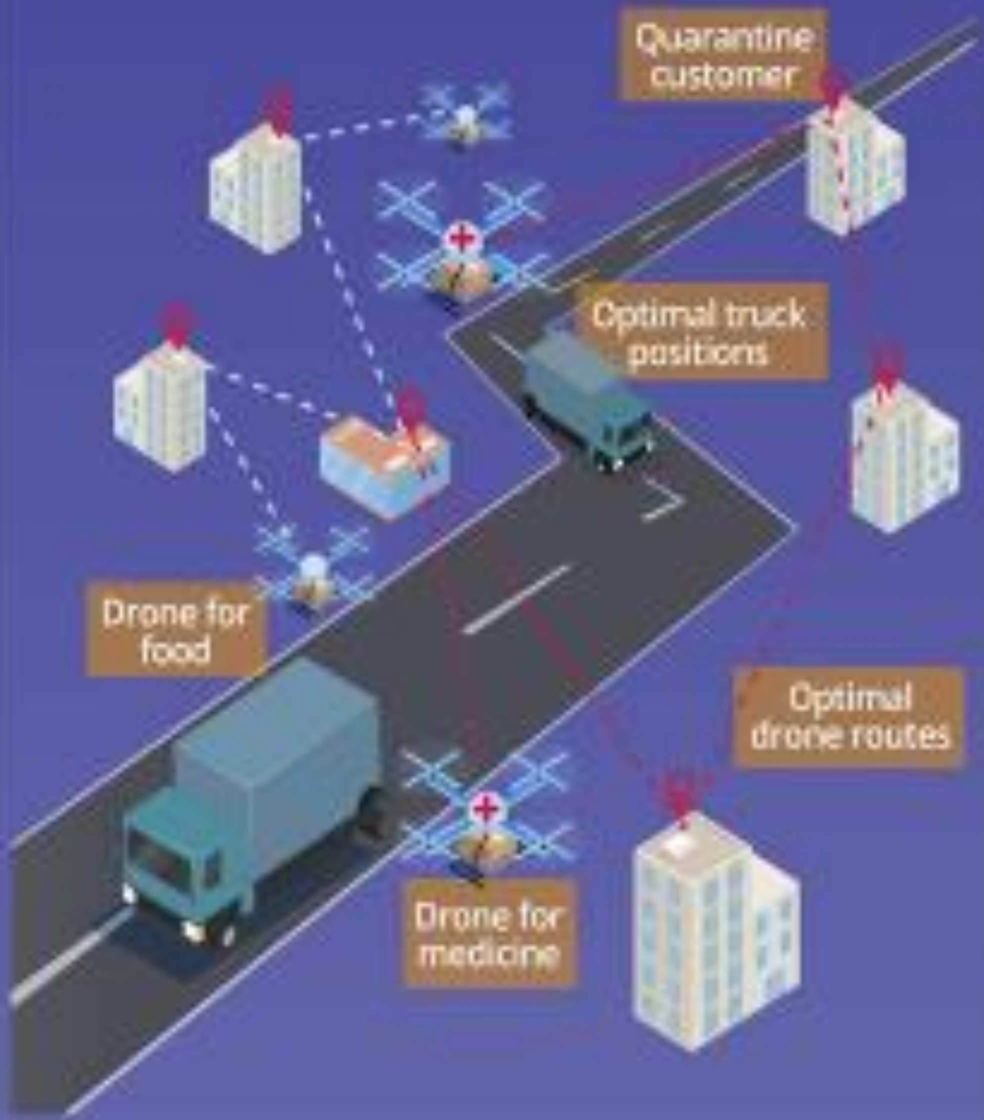
Berthing Decision
Berthing Schedule
Stockyard Plan
Rake Loading Schedule

Simulating the Disruptive Impact of COVID-19 on Supply Chains and Devising Solutions

The outbreak of COVID-19 necessitated a strict lockdown to control infections

But that, combined with situations created by rising infections, disrupted supply chains as well

Based on a comprehensive literature review, **truck-drone synchronized delivery system recommended** to quickly reach customers in severely infected areas while maintaining social distancing



New simulation model created of food supply chain (Public Distribution System) disruption under three scenarios across six months:

Scenario I: Normal operation of the PDS

Scenario II: One facility shut down due to COVID-19

Scenario III: Backup facility to maintain required service level during disruptions

- Shows impact of pandemic on demand, supply, and revenue
- Shows that a backup warehouse at a strategic location is key to maintaining required supply levels

These models can be used to devise robust action plans to tackle pandemic-based disruptions and keep supply chains of essential goods, such as food, medicines, and PPE, running

Unlocking the Potential of Disruption-Resilient Supply Chains

Literature review

Truck-drone synchronized rapid delivery system to high-infection zones

Simulation of India's Public Distribution System (PDS) under three scenarios:

1. Normal operation
2. One warehouse shut down due to COVID-19
3. Backup warehouse present

Backup warehouse at strategic location can help maintain required supply levels

These models can help build resilient supply chains for essential goods during the COVID-19 pandemic and any future pandemics

Dynamic allocation of medical oxygen In Pandemic

Most states have their major cities experiencing an unprecedented number of COVID cases, leading to a dire demand for medical oxygen in those areas.

Several Oxygen Manufacturing plants with specific capacities are spread across the country

Minimize the lead time of the medical oxygen supply chain while ensuring that region-wise oxygen demands are met.

Data Driven Simulation Model

INPUTS

- Location and capacity of oxygen manufacturing plants
- City wise location and demand for medical oxygen

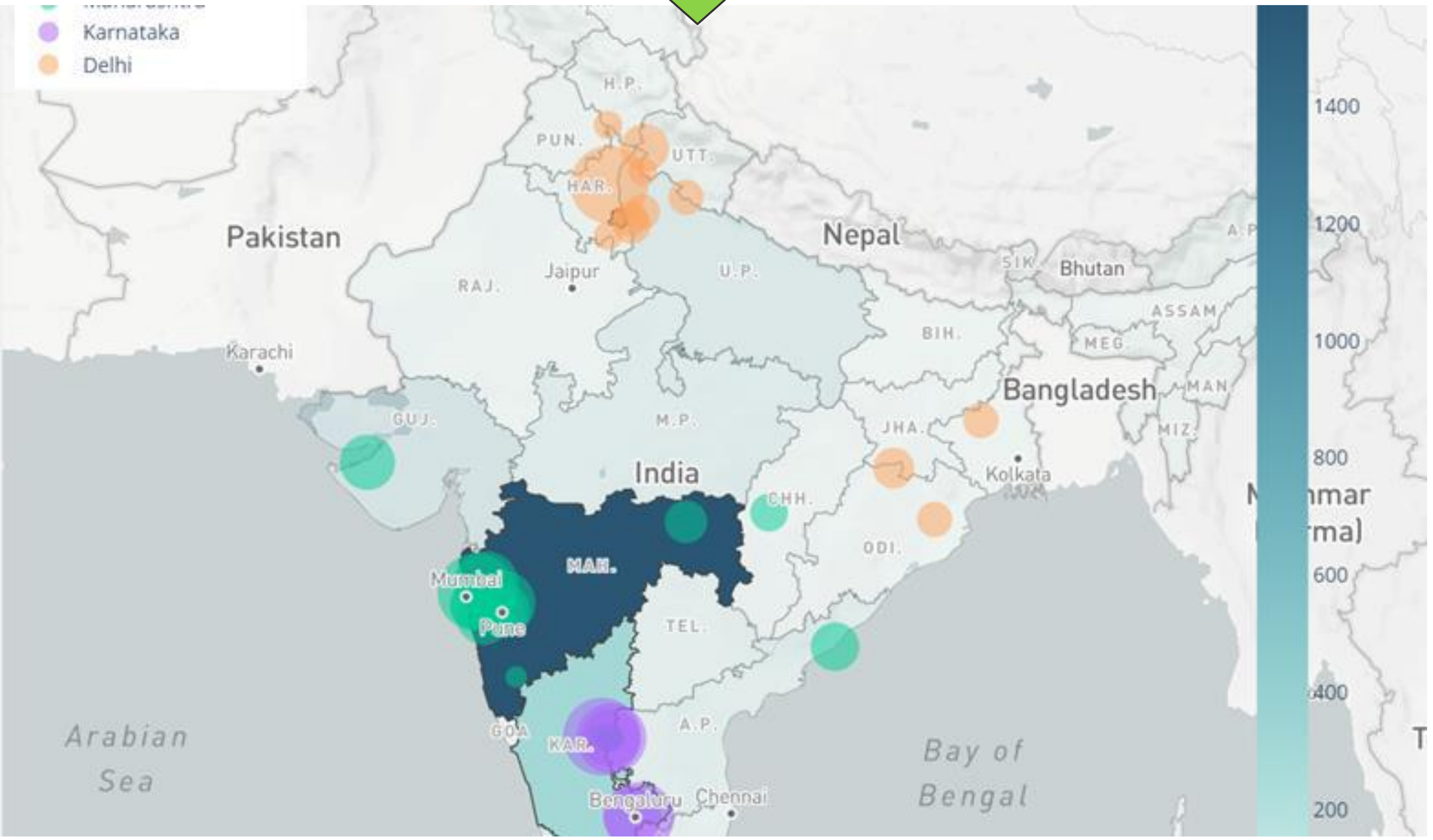
OPTIMIZATION

OUTPUTS

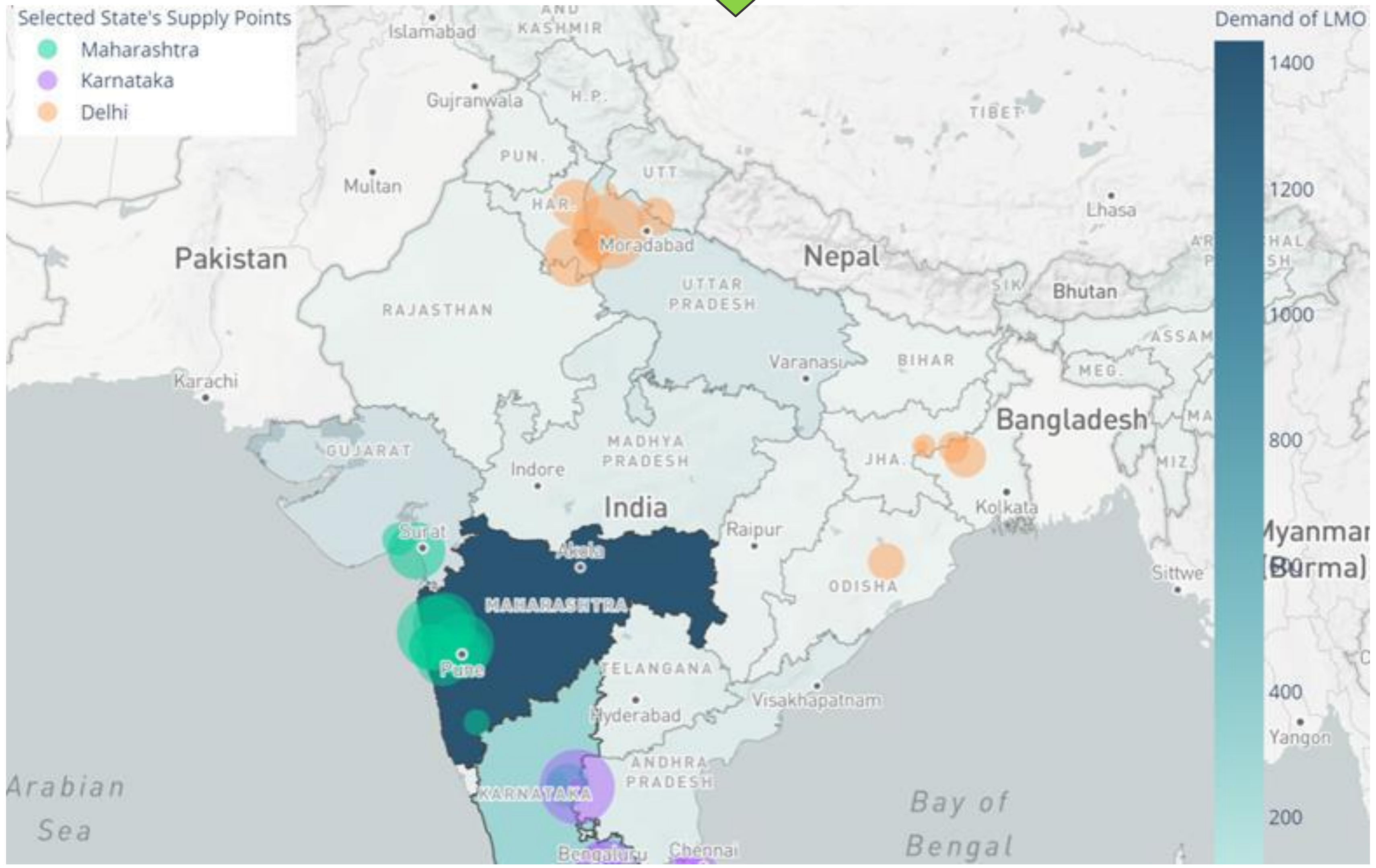
Determination of amount of medical oxygen to be supplied by each plant to various cities

Application of the Data Driven Simulation Model

- Current allocation according to actual dataOxygen distribution during Second Wave
- Map represents real medical oxygen allocation to states on 21 April
- Comparing our model performance with the actual state-wise allocation
- A total of 71 oxygen manufacturing plants have been incorporated to supply the estimated demand .



- Optimized allocation according to model which uses Lp programming to optimally redivide the supply according to the distance and demand
- Model was able to reduce the total distance travelled by oxygen trucks by 44%.
- This leads to lower lead time and fair distribution of oxygen



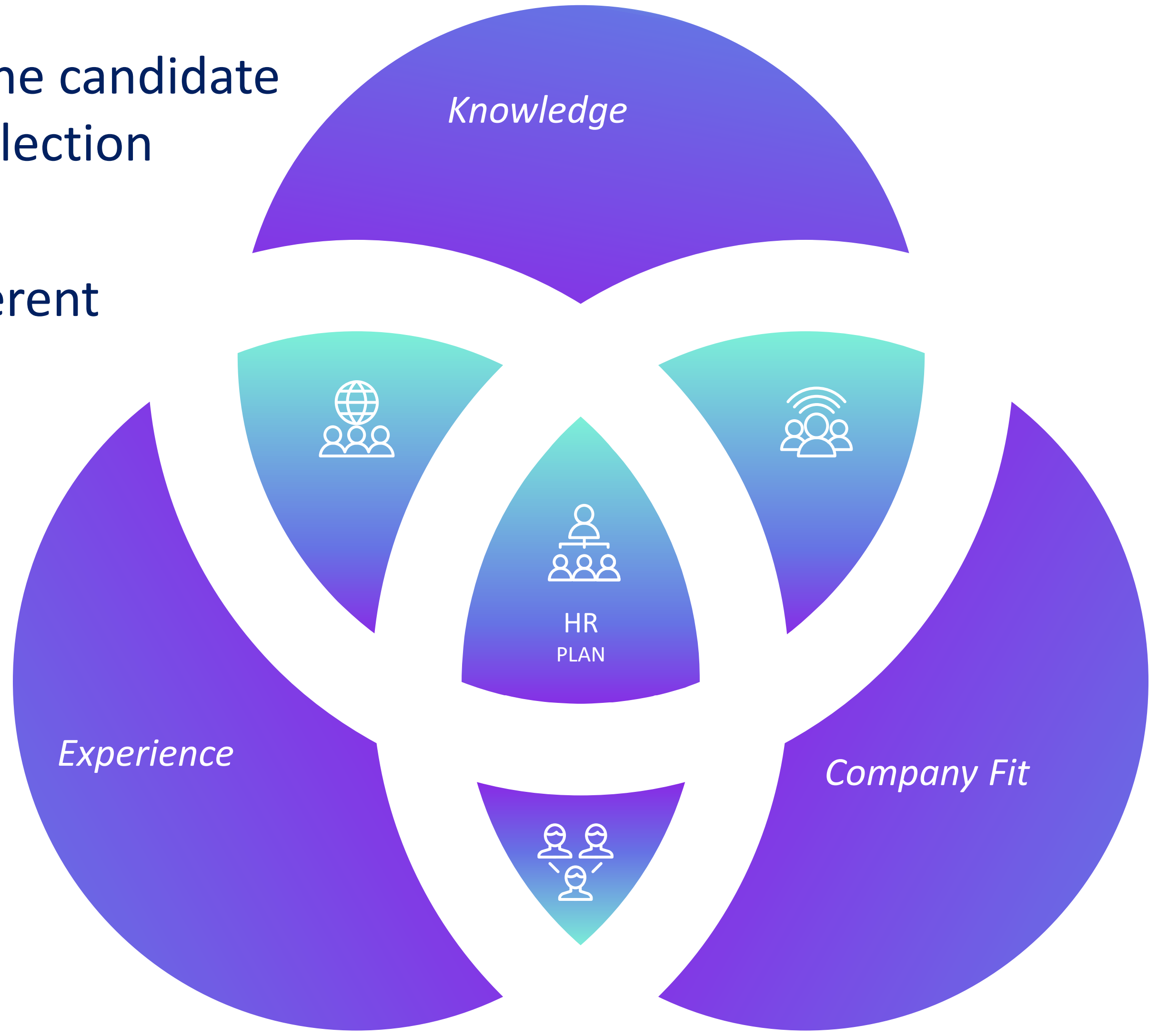
Human Resource Development

Agenda

- Tasked with developing a rubric/collection of caselets to help with interview process
- Cases had to be designed in a manner that quantified specific experience, knowledge and aspects of the candidate
- Cases should also have certain metrics by which candidates could be differentiated from for ease of selection

Defining Job Requirements and Success Metrics:

- Made a deep dive into various interview and hiring rubrics of multiple job positions of similar and different domains to understand the requirements.
- Researched into the diversity of requirements and how they change depending on the scale of the company.



Scenarios prepared to help assess the competency of the candidate

- Product Manager
- Category Manager
- Logistics Manager

Step 1:
Initial meeting to gain understanding of the problem statement.

Step 2:
Refining knowledge and understanding of the requirement

Step 3:
Developing Interview Questions/caselets and rubrics for jobs at a broad scale

Step 4:
Developing Interview Questions/caselets and rubrics for specific jobs and caliber

Step 5:
Provide final documents with quantifiable metrics

Design Roadmap

Industrial Engineering Study in a Power Plant

Objective

- Create a strong resource base for existing operations
- Calibrated at an optimal level with scope to channel promising resources to new/acquired businesses thereby enabling individual and business growth

Solution Approach

- Defined variable components to grasp the scale of the organization (e.g., Site Activities, Line Tripping, Meetings, Line Outages, High Risk Jobs, Job Safety Analysis, PTW)
- Variables are dependent on the location of the organization (Node) and the number of consumers. These variables are used to get the appropriate workload for each role
- Considering the variability in the activities, the model automatically give optimal manpower required for the organization.

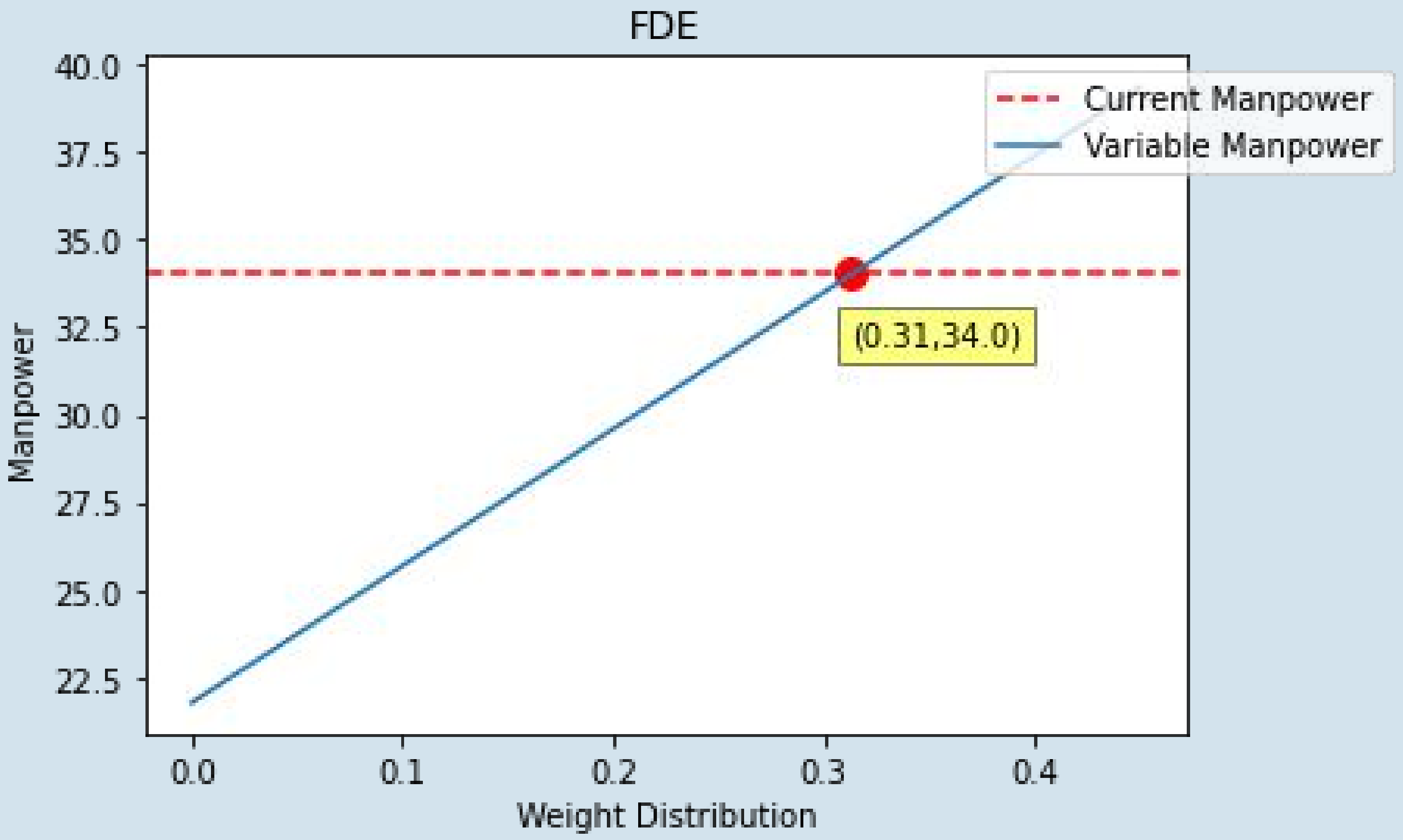
$$\boldsymbol{Required\ Manpower} = \frac{(\mathbf{P}(\boldsymbol{Max_{time}}) \times \boldsymbol{Max_{time}} + \mathbf{P}(\boldsymbol{Min_{time}}) \times \boldsymbol{Min_{time}}) \times \boldsymbol{Frequency} \times \boldsymbol{Management} \times \boldsymbol{T}}{\boldsymbol{\varepsilon}}$$

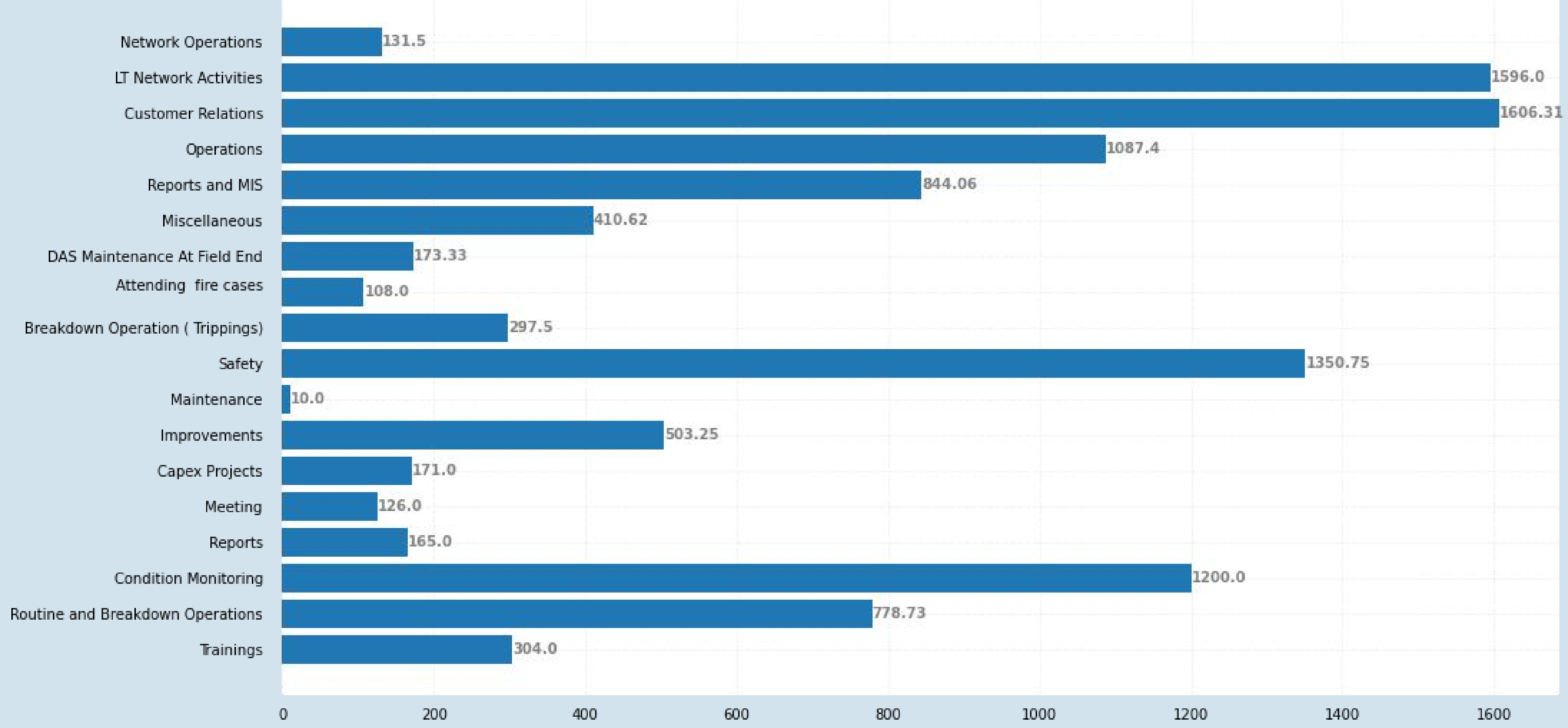
ε depends on the shift (General, Shift 1, Shift 2, Shift 3) of the duty

Required Manpower Analysis

Preliminary Findings

- Analyzed each activity in detail and classified them into daily, weekly, monthly, quarterly, half yearly and annually.
- The activities grouped into some categories. These categories would help establish a correlation between activities and the scale of the organization i.e. number of customers.
- Calculated the manpower required for each role.





Recommendations

- Improve productivity to reduce variability
- Automate some regular activities to save valuable time for the lead engineers and group heads.
- Apply tools or software developed by some programming language (e.g. python) to calculate workload and required manpower. It may help to hire contractual workers as and when required.

Thank you

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