

Managing stockouts in a health care manufacturing factory

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1. Executive Summary:

The objective of this project is to devise feasible strategies to minimize stockouts and optimize inventory levels for a factory manufacturing pharmaceutical products. The mid-term report outlines our progress and accomplishments in the project thus far.

The report contains an official letter from Ved Lifesavers Ltd. and several images as a proof of originality of the data. The data collected for the analysis pertains to raw (packing) materials receiving against purchase order for the years 2021-2023. Data for all the years is consolidated and basic pre-processing techniques are carried out on the data. Metadata and basic descriptive statistics for the dataset is presented. After this, a combination of ABC-VED analysis is performed on the data and the products with the highest profitability are shortlisted. Average monthly demand for these products is computed and the demand is forecasted using ARIMA model. Order lead time and standard deviation of demand for the products is also calculated for further use.

Finally, safety stock and reorder point for the products is calculated using appropriate formulae. All analysis done is accompanied by relevant visual representations.

We will be analysing only 1 raw material for the mid term report. The same analysis will be extended in the final submission.

2. Proof of originality of the data:

Link to the drive containing letter from the organization and data - https://drive.google.com/drive/folders/1JmXokpoq8JN_xKnqoDxGK4T6oQp66SVg?usp=share_link

3. Metadata and Descriptive Statistics:

Snapshot of the raw dataset:

RCV No.	PO_DT	PO_ID	PO_NO	PO_QTY	GRN No.	RCV Date	Item Name	Specs	Batch No.	Mfg Date	Exp Date	Received Qty.	Unit	Unit	Basic Rate	Total Amount
1	05-12-2020	5XC0N03SG17	VLS/RM/20432	3000	0001	05-01-2021	PARACETAMOL	IP	2012PN2448	01-12-2020	30-11-2025	800	1	KG	425	340000
1	05-12-2020	5XC0N03SG17	VLS/RM/20432	3000	0001	05-01-2021	PARACETAMOL	IP	2012PN2447	01-12-2020	30-11-2025	2200	1	KG	425	935000
2	04-01-2021	5Y900EF2W17	003	800	0002	06-01-2021	ISOPROPYL ALCOHOL	IP	OCI/IPA/202012024	01-12-2020	30-11-2023	800	1	KG	128	102400
3	-	-		0	0003	08-01-2021	METFORMIN HYDROCHLORIDE	IP	V2122601	01-01-2021	30-06-2023	309.72	1	KG	0	0
4	28-12-2020	5XZ12NDZM17	VLS/RM/20444	500	0004	11-01-2021	SODIUM STARCH GLYCOLLATE	IP	PR/P/SG-0521/20	01-12-2020	-	500	1	KG	52	26000
5	01-01-2021	5Y9006PF317	001	1250	0005	14-01-2021	DICHLOROMETHANE	BP	213/26122020	06-12-2020	05-12-2022	1250	1	KG	62	77500
6	12-01-2021	5YF0TY04Z1	014	25	0006	16-01-2021	POLYETHYLENE GLYCOL-60	IP	B200265	01-08-2020	31-07-2023	25	1	KG	130	3250
7	08-01-2021	5YB11T8MX7	007	10	0007	16-01-2021	BETAHISTINE DIHYDROCHLORIDE	IP	EDBHD20063	01-12-2020	30-11-2025	10	1	KG	6000	60000
8	13-01-2021	5YG153DJE17	019	220	0008	16-01-2021	BLENDED PELLETS OF RABBIT	IP	PRLL20019	01-12-2020	30-11-2023	220	1	KG	2486.36	546999.2

SGST %	SGST %	CGST %	CGST %	IGST %	IGST %	SGST Amount	SGST Amount	CGST Amount	CGST Amount	IGST Amount	IGST Amount	P.O. No.	Supplier Name	Manufacturer Name
0	0	0	0	18	0	0	0	0	0	61200	0	VLS/RM/20432	MEGHAMANI LLP	MEGHMANI LLP
0	0	0	0	18	0	0	0	0	0	168300	0	VLS/RM/20432	MEGHAMANI LLP	MEGHMANI LLP
9	0	9	0	0	0	9216	0	9216	0	0	0	003	Aastha Chemical	ORGANO CHEM (INDIA)
0	0	0	0	0	0	0	0	0	0	0	0	0	VED LIFESAVERS (P) LTD.	VED LIFESAVERS
0	0	0	0	18	0	0	0	0	0	4680	0	VLS/RM/20444	Prachin Chemical	PRACHIN CHEMICALS
0	0	0	0	18	0	0	0	0	0	13950	0	001	Medicine Chamber	MEGHMANI FINECHEM LTD
9	0	9	0	0	0	292.5	0	292.5	0	0	0	014	Aastha Chemical	INDIA GLYCOLS LTD
0	0	0	0	18	0	0	0	0	0	10800	0	007	ENAL DRUGS PVT LTD	ENAL DRUGS
9	0	9	0	0	0	49229.93	0	49229.93	0	0	0	019	VEDAM LIFE SCIENCE	JOSHKA PHARMA

The relevant variables in the dataset are as follows:

Variable Name	Variable Description	Variable Relevance
RCV No.	Index Number	General Purpose
PO_DT	Date of procuring the purchase order.	Used in lead time calculation and demand forecasting.
PO_QTY	Quantity of goods required in the purchase order.	Used in ABC-VED analysis.
RCV_Date	Date of receiving the raw materials.	Used in lead time calculation.
Item Name	Name of the raw material.	General Purpose
Received Qty.	Quantity of raw materials received.	Used in demand forecasting.
Unit	No. of units	Used for calculating total received qty.

Basic Rate	Unit price of raw material.	Used for calculating total received qty.
Total Amount	Total price of the raw materials purchased.	Used for ABC-VED analysis.

Data Cleaning:

Step-1: Only the relevant columns from the dataset are selected.

Step-2: Total rcv qty is calculated as Received Qty. \times Unit.

Step-3: Shelf life for the products is calculated as the no. of days between Mfg_Date and Exp_Date.

Step-4: Remove any missing values from the dataset. A total of 7 rows were removed.

Step-5: Check for any inconsistent entries in the dataset. None were found.

Snapshot of the cleaned dataset:

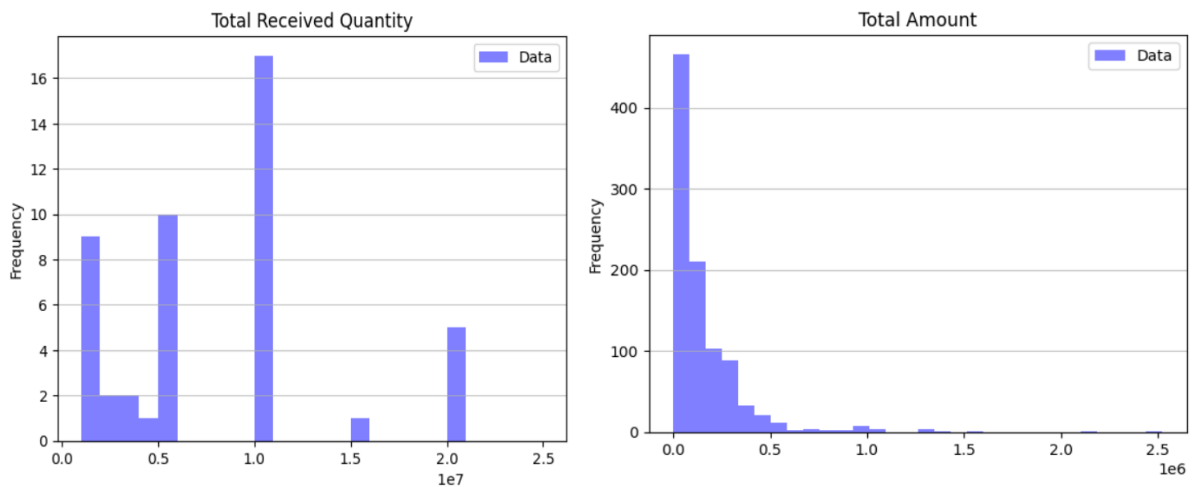
PO_DT	PO_QTY	RCV Date	Item Name	Mfg Date	Exp Date	Received Qi	Unit	Total rcv qty	Unit	Basic Ra	Total Amou
11-01-2021	325	05-02-2021	ACECLOFENAC	01-11-2020	31-10-2025	325	1	325	KG	950	308750
17-02-2021	250	13-03-2021	ACECLOFENAC	01-01-2021	31-12-2025	250	1	250	KG	870	217500
15-03-2021	150	03-04-2021	ACECLOFENAC	01-01-2021	31-12-2025	150	1	150	KG	930	139500
13-04-2021	100	30-04-2021	ACECLOFENAC	01-03-2021	28-02-2026	100	1	100	KG	900	90000
07-12-2021	160	11-12-2021	ACETONE	19-09-2021	-	160	1	160	KG	124	19840
29-08-2022	160	07-09-2022	ACETONE	13-01-2022	31-12-2022	160	1	160	KG	110	17600
13-01-2021	50	22-01-2021	ACICLOVIR	14-05-2020	30-04-2023	50	1	50	KG	3550	177500
30-04-2021	50	07-05-2021	ACICLOVIR	01-02-2020	31-01-2024	50	1	50	KG	3400	170000
06-07-2021	25	22-07-2021	ACICLOVIR	01-02-2020	31-01-2024	25	1	25	KG	3200	80000
13-08-2021	75	03-09-2021	ACICLOVIR	01-03-2021	28-02-2026	75	1	75	KG	3200	240000
12-01-2022	50	24-01-2022	ACICLOVIR	01-11-2021	31-10-2026	50	1	50	KG	3950	197500
07-03-2022	75	06-04-2022	ACICLOVIR	01-02-2022	31-01-2025	15	1	15	KG	3850	57750
07-03-2022	75	06-04-2022	ACICLOVIR	01-02-2022	31-01-2025	60	1	60	KG	3850	231000
07-06-2022	50	21-06-2022	ACICLOVIR	01-12-2021	31-12-2024	50	1	50	KG	3550	177500
13-12-2022	80	26-12-2022	ACICLOVIR	01-10-2022	30-09-2027	80	1	80	KG	4000	320000
17-02-2023	50	01-03-2023	ACICLOVIR	28-08-2022	27-08-2025	50	1	50	KG	3900	195000
22-01-2021	100	01-02-2021	ACRYPOL 934P	01-12-2020	30-11-2023	100	1	100	KG	750	75000
23-06-2021	100	02-07-2021	ACRYPOL 934P	01-06-2021	31-05-2024	100	1	100	KG	750	75000
11-09-2021	260	27-12-2021	ACRYPOL 934P	01-10-2021	30-09-2024	20	1	20	KG	750	15000

Descriptive statistics for the dataset:

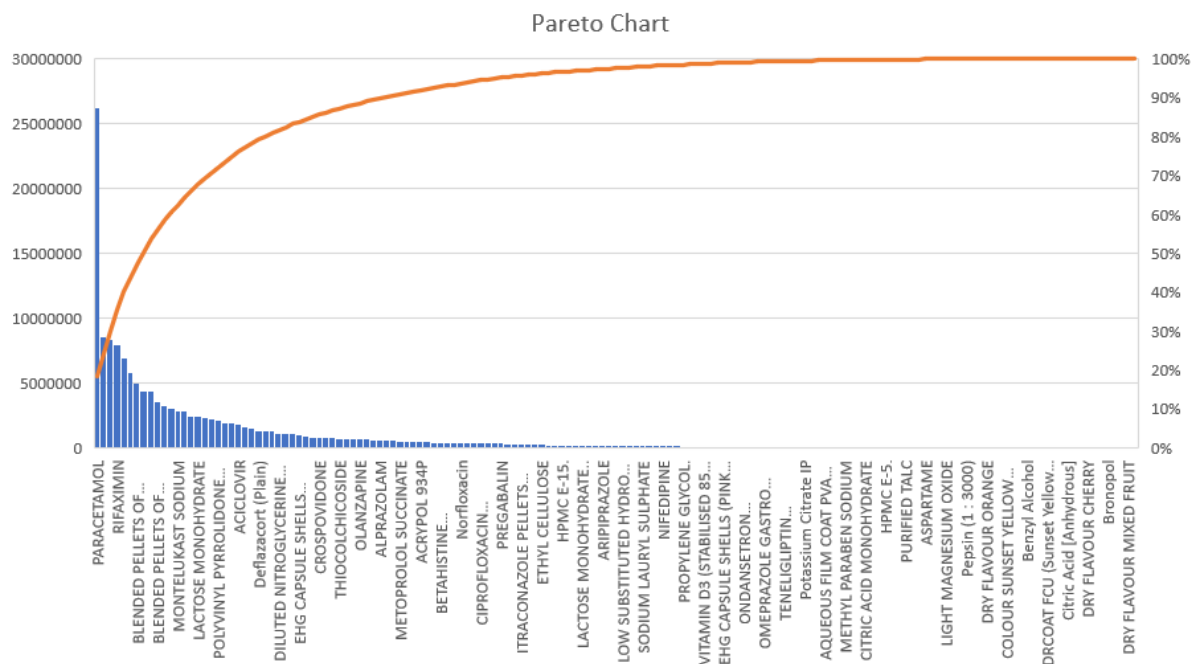
index	Received Qty.	Unit	Basic Rate	Total rcv qty	Total Amount
count	958.0	958.0	958.0	958.0	958.0
mean	37868.84439144051	1.1774530271398747	10871.246245302715	263745.71286743216	151064.0228053236
std	242703.89727478416	1.0087563265835728	52058.72157783058	1699132.445922387	210430.73176455198
min	0.1	1.0	0.08	0.1	0.28
25%	25.0	1.0	410.0	25.0	30850.0
50%	72.5	1.0	1050.0	72.5	87750.0
75%	250.0	1.0	3000.0	250.0	195000.0
max	3500000.0	7.0	550000.0	2450000.0	2523000.0

- There are a total of 154 unique raw materials (item names) in the dataset.
- Earliest date in the dataset: 26-10-2020
- Latest date in the dataset: 21-03-2023
- Total number of days for which the data is collected: 876 days

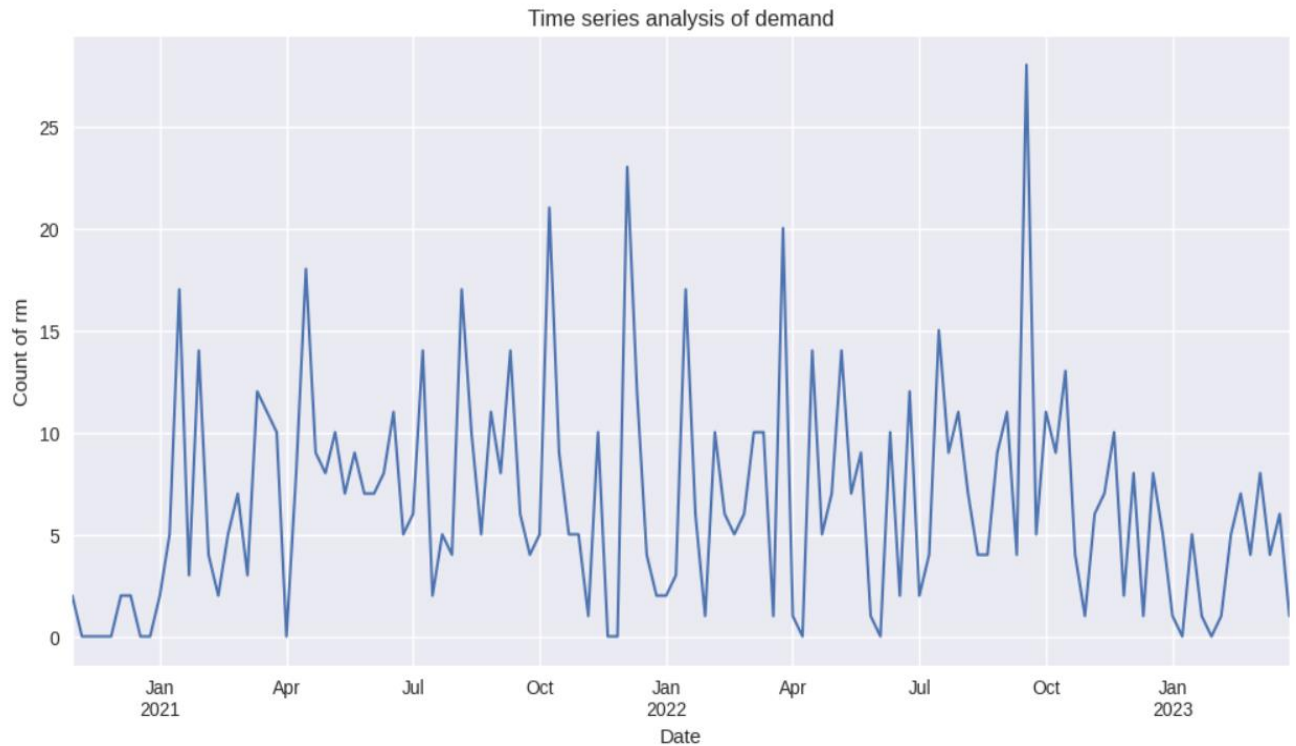
Histogram for Total amount and Total received quantity column is shown below:



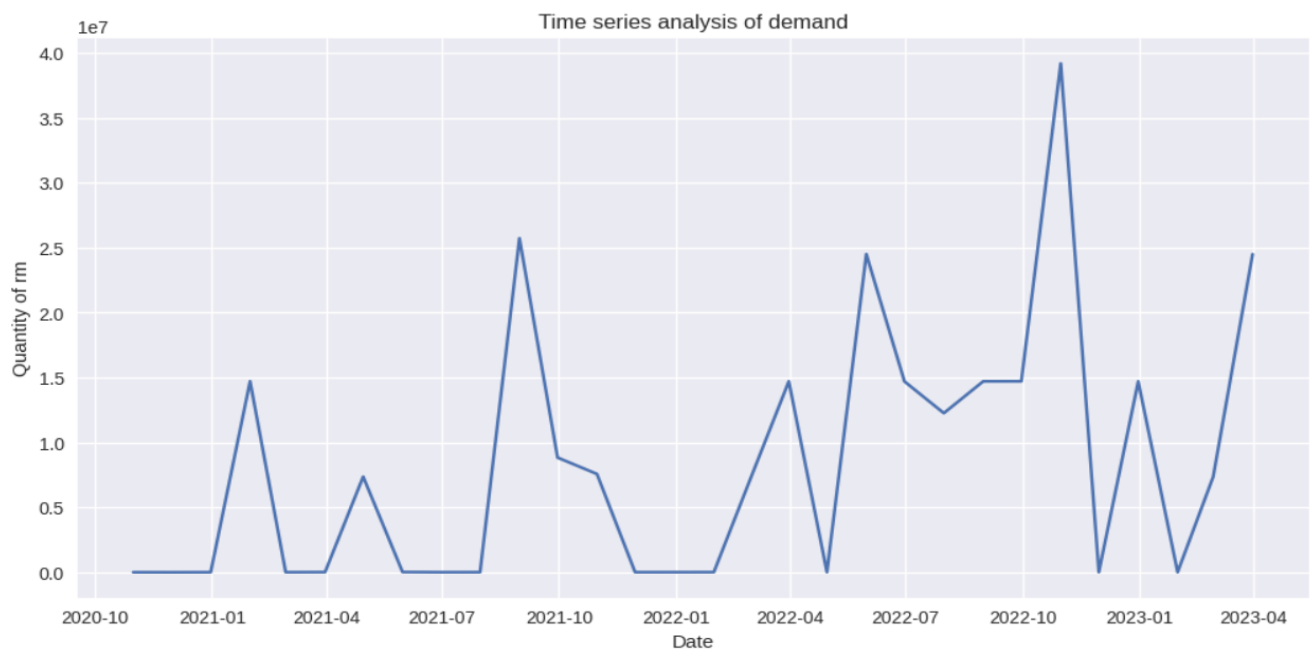
Pareto chart for the data using total amount as value is shown below:



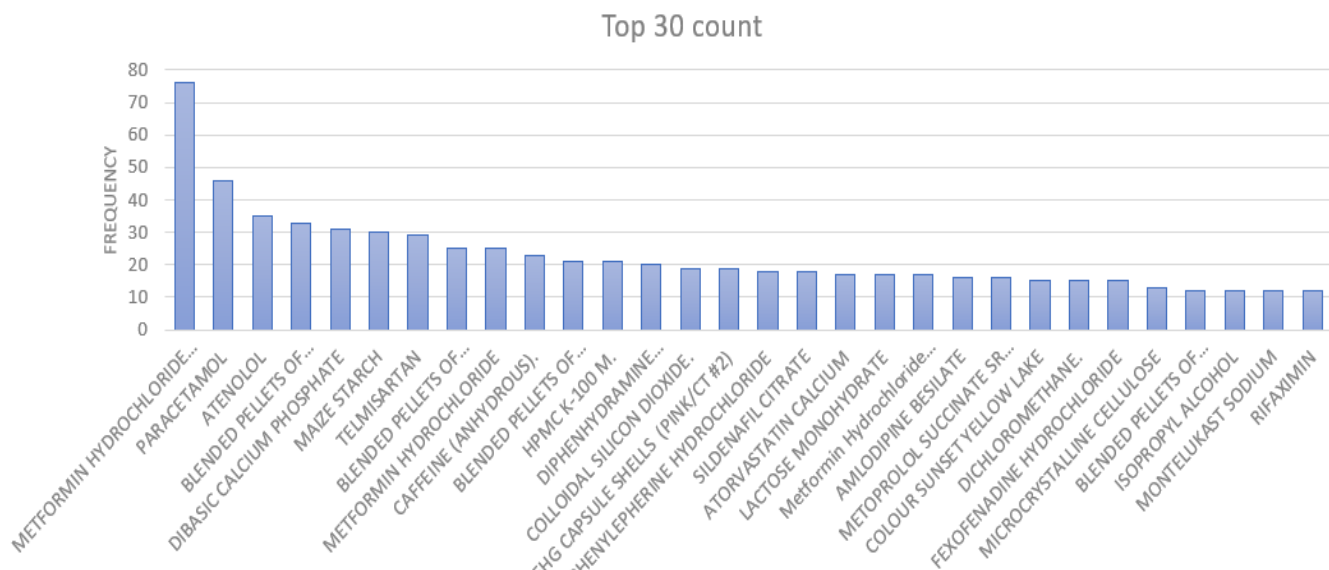
It is clear from the chart that the data follows the pareto principle.



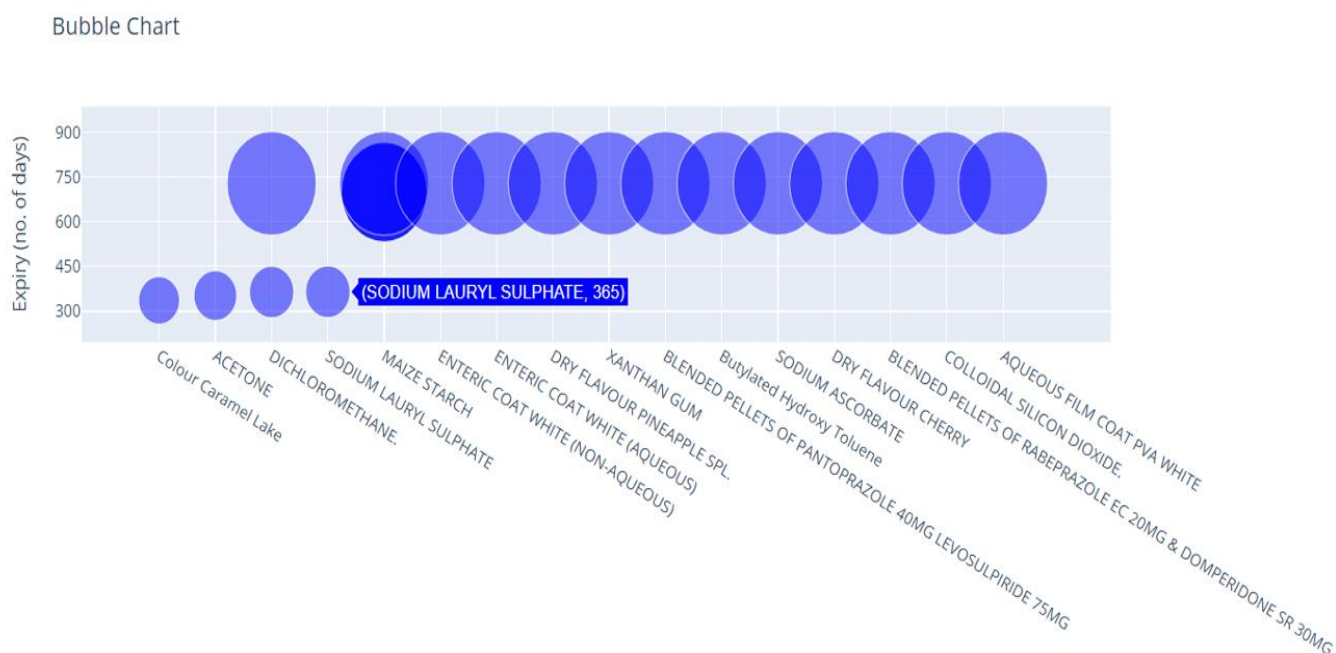
The plot shows the number (count) of raw materials required for the purchase orders weekly. On an average 6.595 number of raw materials were used each week.



The plot shows the quantity of raw materials required for the manufacturing process by date (monthly).



The bar chart displays the frequency of the top 30 item names included in the dataset.



The bubble chart shows the shelf-life duration for 20 products in the dataset with the shortest lifespans. “Colour Caramel Lake” has the minimum shelf life equal to 336 days \approx 1 year.

4. Detailed explanation of analysis:

ABC-VED analysis: This is performed for shortlisting the most profitable raw materials.

ABC analysis is performed on the dataset using the total amount column as value. The items are aggregated and the sum of total amount for all items is calculated using a pivot table in MS Excel. Next, percentage contribution of each item in the sum of total amount is calculated, followed by cumulative percentage calculation. Finally, the items are categorized as “A”, “B” or “C” based on the following logic:

Category	Cumulative %
A	<86%
B	>=86% and <97%
C	>=97%

VED analysis is performed on the dataset using the issue frequency as value. The items are aggregated and the count of item name for all items is calculated using a pivot table in MS Excel. Next, percentage contribution of each item in the issue frequency is calculated, followed by cumulative percentage calculation. Finally, the items are categorized as “V”, “E” or “D” based on the following logic:

Category	Cumulative %
V	<40%
E	>=40% and <75%
D	>=75%

While ABC analysis focuses on the total cost of raw materials issued, VED analysis focuses on the frequency of issuance of these raw materials. Combining ABC-VED analysis we shortlist the products that have the highest total issue amount as well as the highest frequency of usage, thereby having highest profitability.

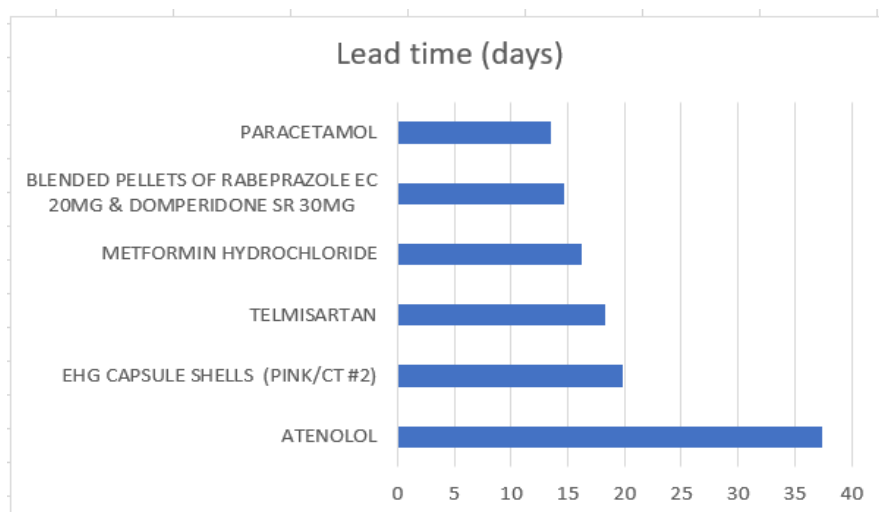
Result for the ABC-VED analysis is shown in the table below:

	A	B	C
V	6	9	1
E	2	17	18
D	0	6	124

We will only be focussing on items that belong to the “V-A” category.

Lead time calculation: Lead time for the shortlisted products is calculated in the excel sheet as RCV_Date – PO_Date.

Item Name	Lead time (days)
ATENOLOL	37.4
EHG CAPSULE SHELLS (PINK/CT #2)	19.8
TELMISARTAN	18.3
METFORMIN HYDROCHLORIDE	16.3
BLENDED PELLETS OF RABEPRAZOLE EC 20MG & DOMPERIDONE SR 30MG	14.7
PARACETAMOL	13.5



Demand Forecasting: Demand forecasting is done using ARIMA (auto regressive integrated moving average) model in python. The

data (for atenolol) is first converted into a format suitable for forecasting.

	issue_qty
date	
2021-02-28	600.32
2021-03-31	950.00
2021-04-30	200.00
2021-05-31	50.00
2021-06-30	150.00

After this, ADF test is applied on the data to check if it is stationary.

```
ADF Test Statistic : -4.327019974609467
p-value : 0.00039871283712892734
#Lags Used : 2
Number of Observations Used : 22
strong evidence against the null hypothesis(Ho), reject the null hypothesis. Data has no unit root and is stationary
```

Then, the parameters of the model are estimated using autocorrelation plots and partial autocorrelation plots.

Finally, the model is fitted on the data.

Safety stock and Reorder point calculation: First we calculate the average monthly demand and standard deviation of demand during lead time for the product “Atenolol” using python. We will be converting all time related variables to unit of months.

```
Average monthly demand: 245.0128 units
Lead time: 1.25 months
Standard deviation of demand during lead time: 276.52812532543595 units
```

The formula used for safety stock calculation is:

$$\text{Safety Stock} = Z \times \sigma_{\text{demand}} \times \sqrt{L}$$

where,

Z – number of standard deviations required to achieve the desired service level. Can be found in a Standard Normal distribution table.

σ_{demand} – Standard Deviation of demand during lead time.

L – Lead time in appropriate units.

We calculate safety stock for a desired service level of 90%. Using a standard normal distribution table, it can be obtained that $Z = 1.28$ for a 90% service level.

Using these values, we get the value of safety stock as **396 units**.

Formula used for reorder point calculation is:

Reorder Point = (Average monthly demand \times Lead time) + Safety stock

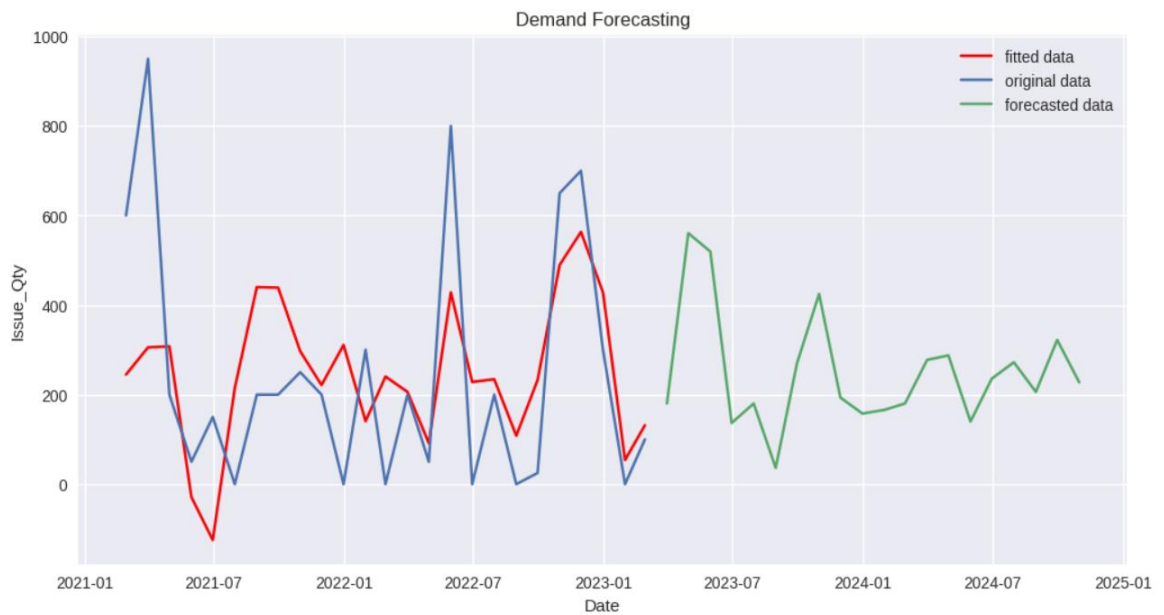
Reorder point for atenolol is **702 units**.

5. Results and Findings:

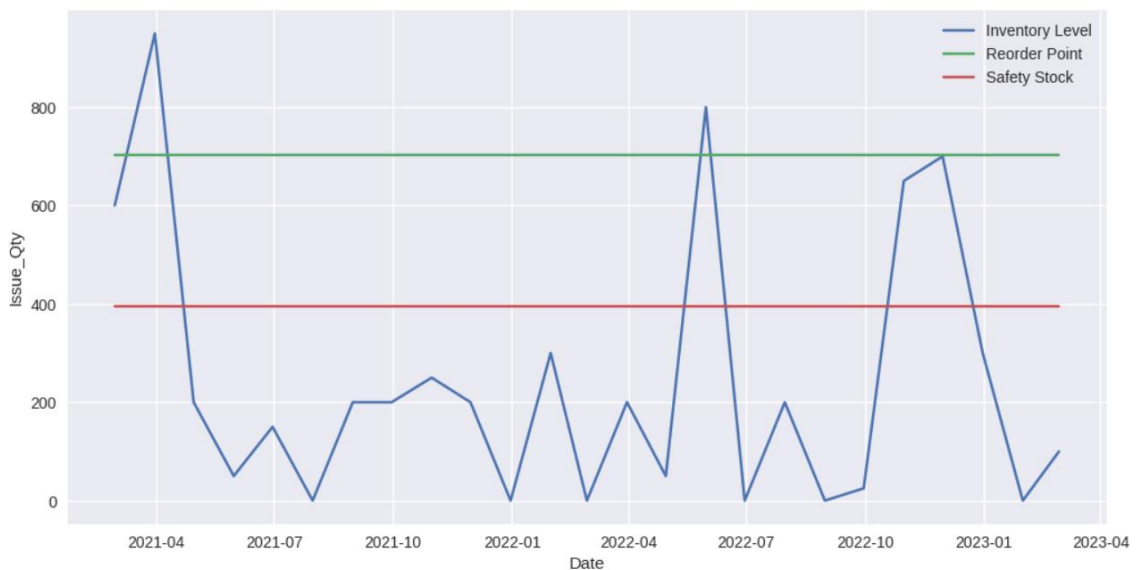
- The most profitable raw materials of the factory were shortlisted.

	Shortlisted Products
1	ATENOLOL
2	BLENDED PELLETS OF RABEPRAZOLE EC 20MG & DOMPERIDONE SR 30MG
3	EHG CAPSULE SHELLS (PINK/CT #2)
4	METFORMIN HYDROCHLORIDE
5	PARACETAMOL
6	TELMISARTAN

- Demand was forecasted for the product “Atenolol”.



- Safety stock and reorder point for “Atenolol” were calculated as 396 units and 702 units respectively.



- Due to high variability in the demand data the value of safety stock and reorder point is quite high.
- We will intelligently find and remove outliers in the data for the next analysis to prevent this.