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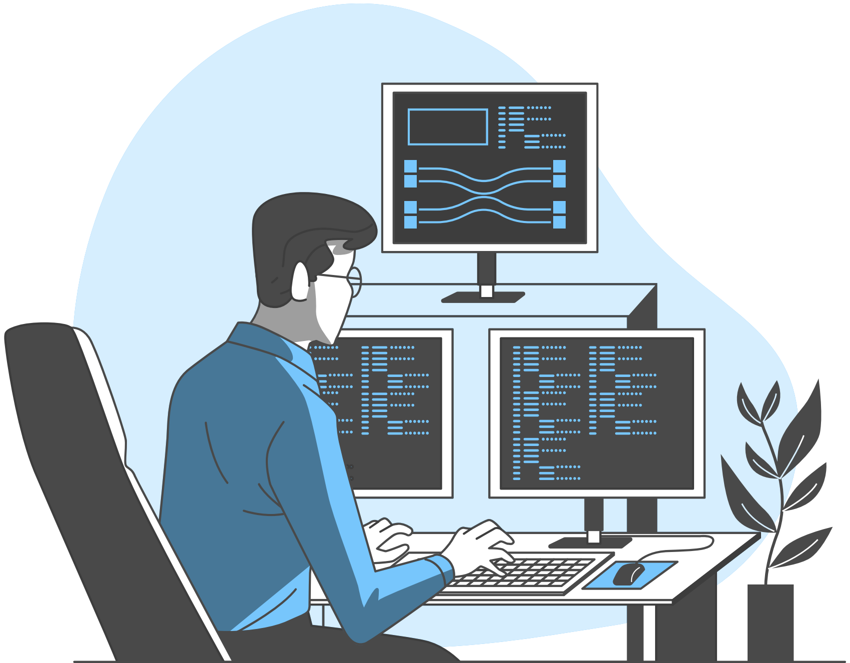

Determining Optimal Stock and Reorder Level for Inventory on a Monthly Basis

Team 6: MSO Pandas

Problem Context

Develop a model (for them to compare with their existing model) that automatically assigns

- Optimal Stock Level (Q*)
- Optimal Reorder Level (r*)

for every single inventory item.

Objective

Propose an inventory model minimizing unnecessary costs while meeting demands

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Methodology Overview

01 Data Wrangling and Pre-analysis

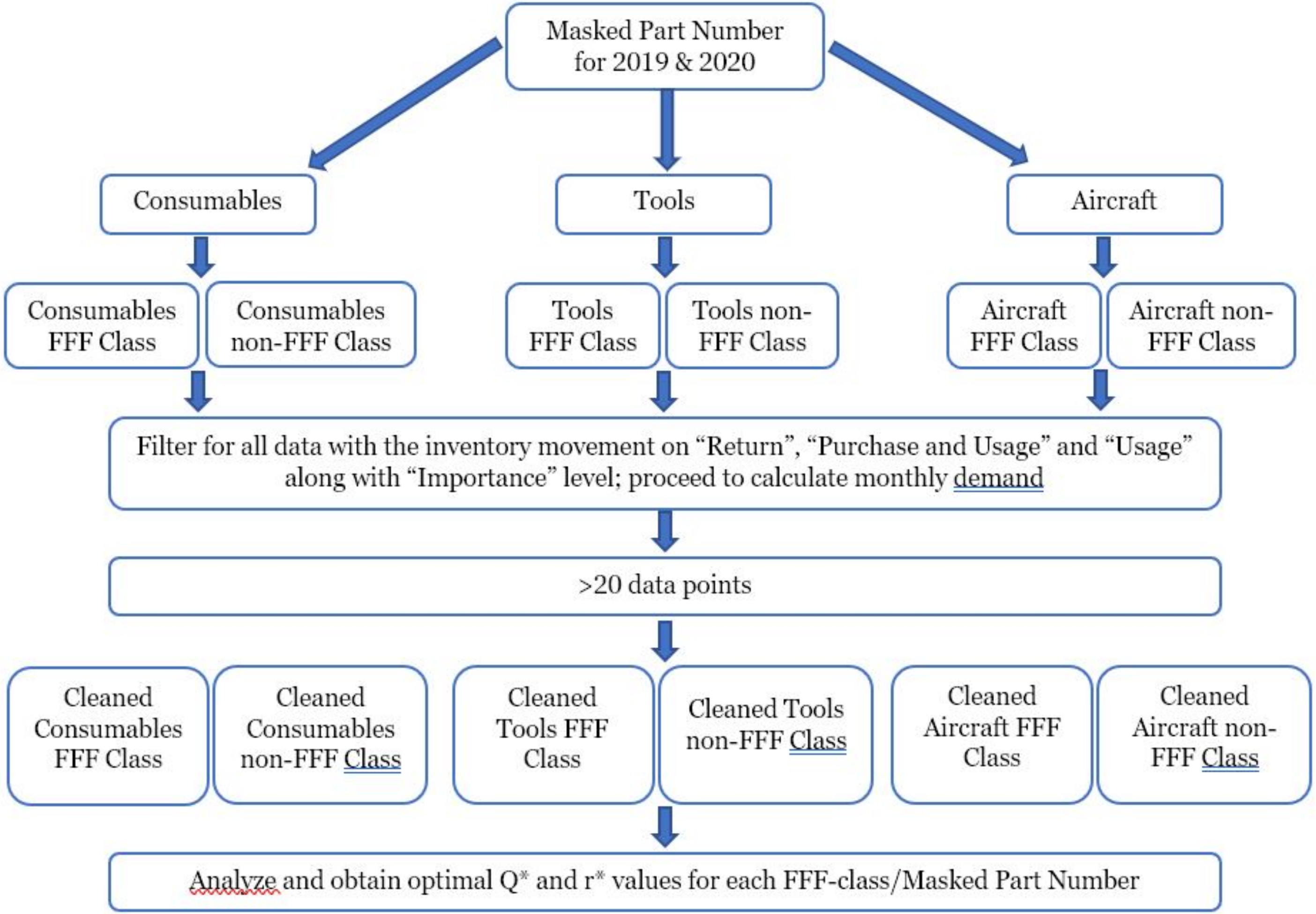
02 Demand Model

03 Inventory Model

04 Optimal Q* and r*

Data Wrangling

No.	Title	Remarks
1	**Masked Part Number**	Each Part Number represents different product
2	**Inventory Movement Description**	Either return, purchase, purchase & return, usage, reverse purchase
3	**Masked FFF-class**	Family of interchangeable parts, parts are interchangeable if they belong to the same FFF-class
4	**Item Category**	Consists of Aircraft, Consumables and Tools
5	**Importance**	High, Medium or Low
6	Quantity	For calculating monthly demand
7	Entry Date	-
8	Amount (SGD)	For getting the original/premium price


Masked Part Number for 2019 & 2020
Consumables
Tools
Aircraft
Consumables FFF Class
Consumables non-FFF Class
Tools FFF Class
Tools non-FFF Class
Aircraft FFF Class
Aircraft non-FFF Class
Filter for all data with the inventory movement on "Return", "Purchase and Usage" and "Usage" along with "Importance" level; proceed to calculate monthly demand
>20 data points
Cleaned Consumables FFF Class
Cleaned Consumables non-FFF Class
Cleaned Tools FFF Class
Cleaned Tools non-FFF Class
Cleaned Aircraft FFF Class
Cleaned Aircraft non-FFF Class
Analyze and obtain optimal Q* and r* values for each FFF-class/Masked Part Number

Pre-analysis

Pre-analysis

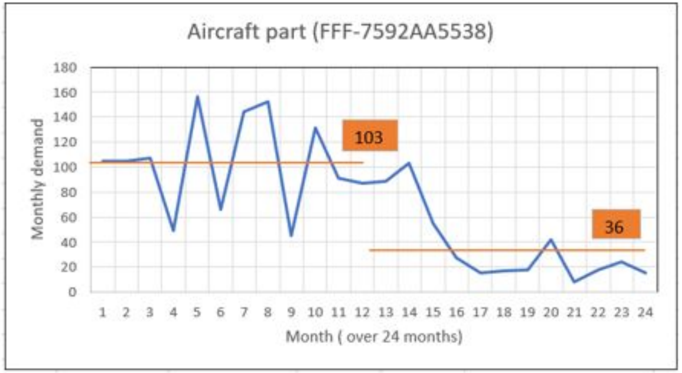
- We first compare the annual demand between 2019 and 2020 for each FFF-Class/masked part number for their respective item category.

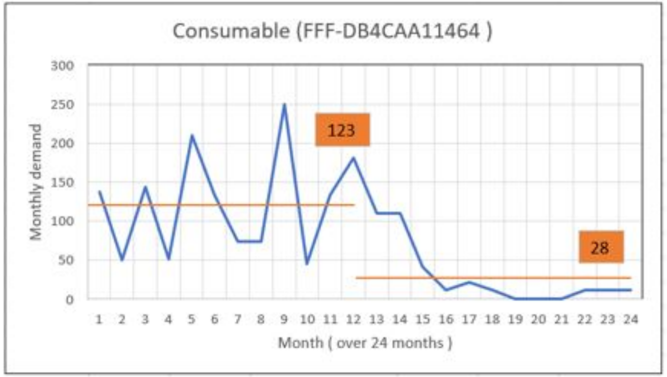
Masked FFF Class	Item Category	totaldemand2019	totaldemand2020
FFF-7592AA5538	Aircraft	1238	431
FFF-MS35AA15274	Aircraft	1237	134
FFF-BACCAA9865	Aircraft	1211	333
FFF-BACRAA10257	Aircraft	1201	76
FFF-NAS6AA43180	Aircraft	1199	73

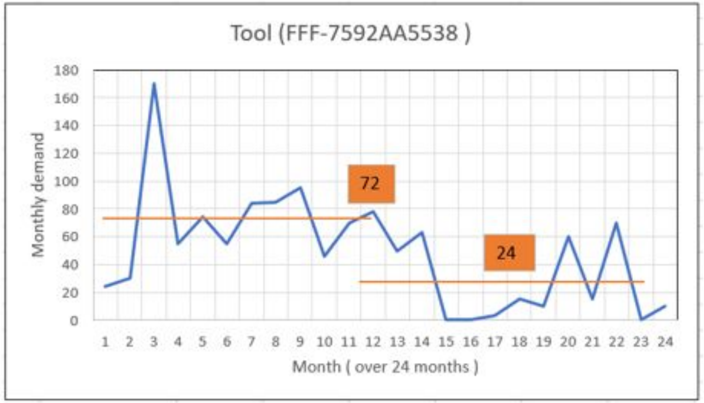
Masked FFF Class	Item Category	totaldemand2019	totaldemand2020
FFF-DB4CAA11464	Consumables	1485.0	343
FFF-TSDSAA18126	Consumables	1186.0	277
FFF-TSDSAA18070	Consumables	1016.0	502
FFF-TSDSAA18094	Consumables	906.0	355
FFF-2E98AA2311	Consumables	850.0	254

Masked FFF Class	Item Category	totaldemand2019	totaldemand2020
FFF-4801AA3847	Tool	22790	4189
FFF-6515AA4669	Tool	9600	3007
FFF-TS27AA26151	Tool	4596	16
FFF-TS27AA26152	Tool	2044	21
FFF-M819AA14345	Tool	866	253

➢ Then we plotted time-series graphs to see how the monthly demand have changed across the 2 years (before vs after COVID pandemic) for different items in each item category.



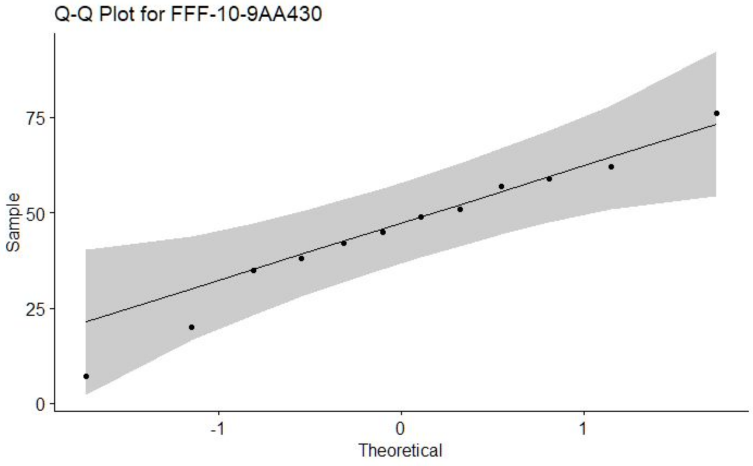


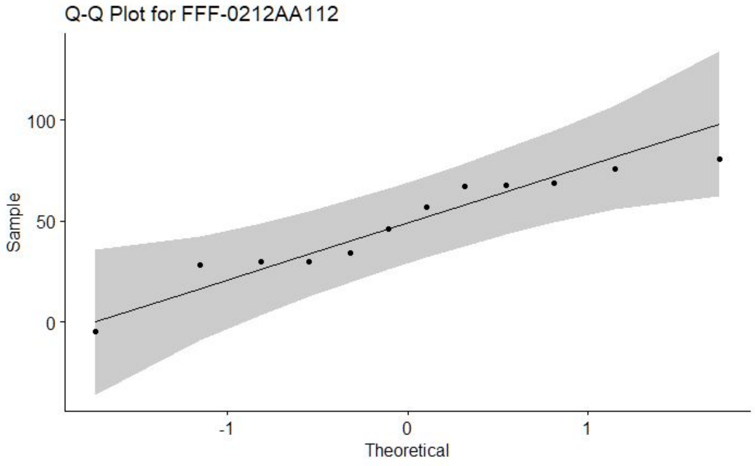


Demand Model

Demand Model - Q-Q Plot (Stats)

- We want to determine the distribution of our demand
- Data points are too little for Central Limit Theorem
- Q-Q Plot to visualise if our data is normally distributed
- Can make an estimate, but cannot give us a definite answer





Demand Model - Wilk-Shapiro Test (Stats)

- We want a definite answer

First, we set up a hypothesis test with alpha value = 5%

H_0: Demand is normally distributed

H_1: Demand is not normally distributed

Using R to determine p-value, for “FFF-10-9AA430” and “FFF-0212AA112”, p-value = 0.07308 and 0.31750 respectively, > 5% (alpha value).

We do not reject our null hypothesis, hence we can conclude with 95% confidence that the demand data is normally distributed.

Inventory Model (Q,r)

Inventory Model

Parameters	**(Q,r) Model**	**Our Data**
Demand	Random	Random
Lead Time	Fixed & Known	Not Fixed & Known
Holding Cost	Known/ Estimated	Estimated
Stockout Cost	Known/ Estimated	Estimated
Fixed Setup Cost	Known	Unknown
Independent Products	Yes	Yes
Batch Ordering	Yes	Yes

Assumptions made: Lead time = 30 days, fixed setup cost = $500

(Q,r) Model Formulation

To formulate (Q,r) model to solve for:

Minimise {fixed setup cost + stockout cost + holding cost}

The corresponding optimal solutions are:

$$Q^* = \sqrt{\frac{2AD}{h}} \quad \text{and} \quad r^* = \theta + z\sigma$$

Parameters needed to determine Q* and r*:

- Demand (D): the mean of demand per month
- Holding cost (h): assumed to be 20%/12 per month of the unit cost of inventory item
- Fixed cost (A): assumed to be fixed at $500
- Expected demand during supply lead time (θ): mean demand monthly as supply lead time is assumed to be 1 month
- Standard deviation of demand (σ)
- Stockout cost (k): unit stock out cost = max. unit cost – min. unit cost
- $$z = \frac{kD}{hQ + kD}$$

Solving for Q* and r*

Calculated Q* and r*:

FFF-Class	**Q***	**r***
FFF-10-9AA430	243	78
FFF-0212AA112	175	64

Performance measure for Q* and r*

Performance measures analysis:

Performance Measure	FFF-10-9AA430	FFF-0212AA112
Expected Stockout	0.05785	1.14
Expected Leftover Inventory	154.43	106.61
Fill Rate	0.998	0.9765
Total Expected Cost	216.20	327.30

For classes of "high" importance, we want to ensure that probability of stockout is as low as possible.

Recalculating new r*

By using fill rate (exact) formula, we recalculated optimal reorder point (r*) by equating fill rate to be ~100%

$$0.9999 = 1 - \frac{1}{Q^*}\left[B\left(r_{new}\right) - B\left(r_{new} + Q^*\right)\right]$$

(Fill rate)

For FFF-0212AA112: $0.9999 = 1 - \frac{1}{175}\left[B(r_{new}) - B(r_{new} + 175)\right]$

For FFF-10-9AA430: $0.9999 = 1 - \frac{1}{243}\left[B(r_{new}) - B(r_{new} + 243)\right]$

Comparing between initial r* and new r*

Initial Q* and r*:

FFF-Class	Q*	r*
FFF-10-9AA430	243	78
FFF-0212AA112	175	64

Newly calculated Q* and new r*:

FFF-Class	Q*	r^*_{new}
FFF-10-9AA430	243	95
FFF-0212AA112	175	118

Comparing the initial r* and new r*

Q* and Initial r*

Performance Measure	FFF-10-9AA430	FFF-0212AA112
Expected Stockout	0.05785	1.14
Expected Leftover Inventory	154.43	106.61
Fill Rate	0.998	0.9765
Total Expected Cost	216.20	327.30

Performance measure of optimal Q and initial r

Q* and new r*

Performance Measure	FFF-10-9AA430	FFF-0212AA112
Expected Stockout	0.004508	0.004883
Expected Leftover Inventory	171.01	157.11
Fill Rate	0.9999	0.9999
Total Expected Cost	223.73	390.37

Performance measure of optimal Q and new r

Performance Measure: Total Expected cost

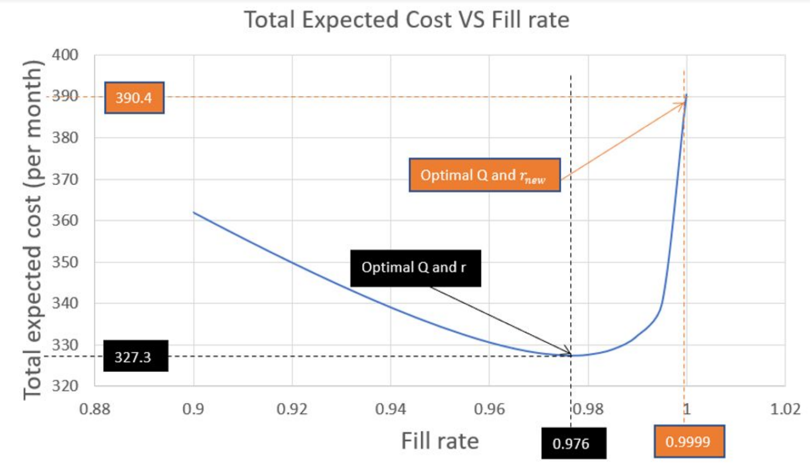


Figure 2: Plot of Total Expected cost (per month) against fill rate for FFF-0212AA112

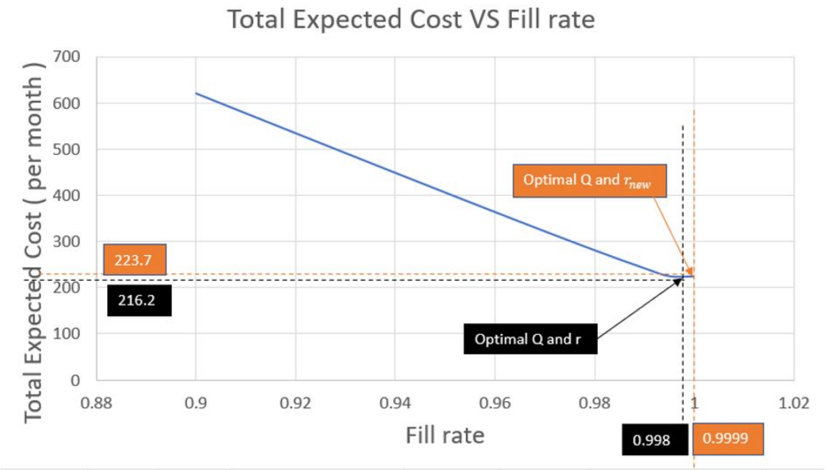


Figure 4: Plot of Total Expected Cost (per month) against fill rate for FFF-10-9AA430

Sanity check for r*: T-distribution

	FFF-10-9AA430	FFF-0212AA112
Sample size, n	12	12
Sample mean, $\bar{x}$	45.083	45.833
Sample standard deviation, s	18.754	24.679

Since the sample size (n) is small and population variance (σ^2) is unknown, but the demand distribution is normal, we can use the t-distribution to find the Confidence Interval of the mean monthly demand.

$$\bar{X} - t_{n-1,\alpha/2}\frac{S}{\sqrt{n}} \leq \mu \leq \bar{X} + t_{n-1,\alpha/2}\frac{S}{\sqrt{n}}$$

Sanity check for Q* and r*: T-distribution

Previously calculated Q* and new r*:

FFF-Class	Q*	r*
FFF-10-9AA430	243	95
FFF-0212AA112	175	118

CI obtained for the demand of FFF-10-9AA430 is [33.167, 56.999]

CI obtained for the demand of FFF-0212AA112 is [33.153, 64.154]

With 95% confidence, the true monthly demand lies within the CI calculated. Hence, since our reorder points r for both FFF-classes are higher than their respective upper bounds of the 95% CI, we can be confident that on average we are able to meet the demand during the 1 month of supply lead time.

Data/Logistics challenge

- Not all supply lead time is 30 days
- Unknown exact holding cost
- Unknown fixed cost and stockout costs

Thank you.

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Reorder point(r) VS fill rate graphs

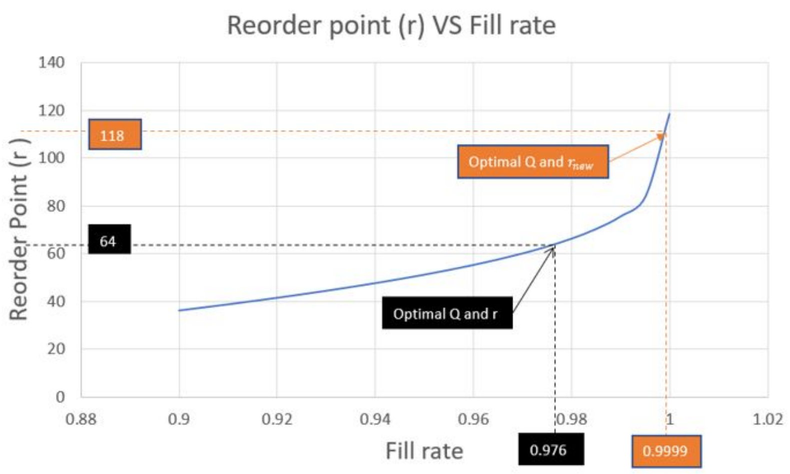

Figure 1: Plot of Reorder point (r) against fill rate for FFF-0212AA112

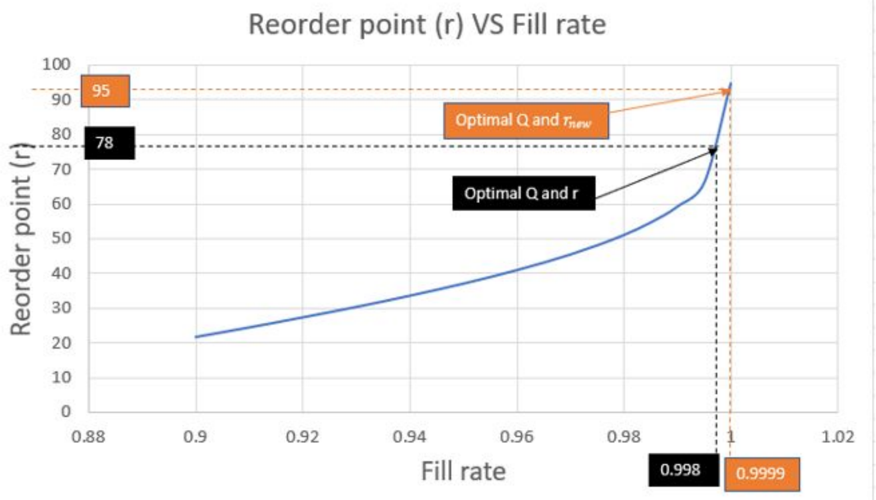

Figure 3: Plot of Reorder point (r) against fill rate for FFF-10-9AA430