PROJECT REPORT

«Optimisation of supply network for importing coffee beans»

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2023

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1 Introduction

We appreciate the opportunity to work with Beanie Limited and assist you in optimizing the operations at the Caserta warehouse. We understand your concerns regarding the management of certain aspects in the warehouse, particularly regarding stock levels and order fulfillment. Our team at SimiUPF is dedicated to resolving these issues and ensuring smooth operations for your business.

After thoroughly analyzing the situation at hand, we have identified two key challenges that need to be addressed: excessive stock levels and frequent stockouts. The year 2021 was characterized by high stock levels, which resulted in increased costs and tied up valuable financial resources. Additionally, there were numerous instances where the warehouse experienced stockouts, leading to delays in fulfilling client orders.

To tackle these challenges, we propose implementing comprehensive recommendations that focuses on optimizing the ordering process and inventory management. We are ready to provide our methodology and a consistent solution to back up our recommendations. Our primary goal is to minimize stock levels while ensuring that clients' needs are met without any delays. By achieving this balance, we can significantly reduce costs associated with excess inventory and improve customer satisfaction.

1.1 Case study

Beanie Limited is a coffee roasting company. It distributes raw coffee beans to clients from Southern Europe and the Mediterranean from its warehouse located in Caserta. According to the data you, Elisa, provided us, we can see that Lead Time (Delivery time) should be 7 days but oftentimes it is not respected, supply comes in either before or way after the expected date of arrival which causes a lot of problems either with stockouts or contrary overstock. Also, the demand itself is quite random, this makes inventory management even more difficult. All of this poses a question of whether it is better to have plenty of stock which results in higher inventory holding but allows to almost always satisfy customer demand or to have lower stock, save up on inventory costs but have more back-order costs when we are unable to meet the demand. The perfect solution would be to capture both of these in one policy that would be able to provide enough stock at any time and still be not expensive in terms of holding inventory costs.

1.2 Goals

Our team aims to find a solution and provide recommendations that will allow your company to minimize inventory costs but meet all customer demands. First, we will study the performance of your warehouse and then proceed with our suggested policy.

2 Performance of warehouse in 2021

Below we summarised the data you provided us in the following Table (1). We see that demand has a mean of 50149, a minimum of a measly 1381, and maximum amount of 107790. This indicates that we are dealing with highly variant demand, this also corresponds to high variance in *amount_in_stock* left. Therefore, as a part of our solution, we should focus on how to smoothen out the number of stock to have lower inventory costs and avoid potential backorder costs.

Table 1: Performance of Caserta Warehouse

	amount_in_stock	demand_quantity	LT
mean	359941.218	50149.196	7.317
std	**475980.653**	**14220.766**	1.846
min	-802079.121	1380.990	4.000
25%	11902.539	40200.062	6.000
50%	313724.586	50873.131	7.000
75%	720190.548	59385.010	9.000
max	1361247.271	107790.972	12.000

In order to visualise what we are dealing with, below - Figure (1) we plotted the stock left in the warehouse after each day. Ideally at the end of a day we should have 0 stock meaning we will not have any inventory costs. Due to random lead-time and demand this is impossible to achieve, that is why you had at times either high amounts of stock or negative amounts of stock - backorders. Below is the picture showing how amount of stock evolved over time.

Figure 1: Warehouse stock in 2021

As we can see, most of the time there was too much stock. Such behaviour lasted for the first 3 quarters and then in Q4 there were a lot of backorders. This might be a result of both underestimating demand during the first 3 quarters and overestimating in the last one.

In order to measure performance we propose using the area under the line plotted above. The best performing policy, once implemented should have almost no area under the curve. Therefore, we propose the following measure:

$$Area = Area_{above\,0} + Area_{below\,0} \tag{1}$$

By calculating this measure we are able to find that policy implemented in 2021 year scored 172916558. Now this number might seem totally out of touch, later we will get back to it once we propose our strategy. Alternatively, we could have calculated total costs of inventory (blue shaded area) along with backorder costs (red shaded area) with different weights depending on what we are prioritizing. To see exactly what happens with demand and leadtimes we plotted their corresponding distributions. Below are distributions of both demands and leadtimes. We observe that both of them follow roughly a normal distribution. This will help our analysis greatly. From the charts above Figure (2) we see that on average Lead Time is around 7-8 days. Sometime supply arrives after only 4 days but there are cases when delay is up to 12 days.

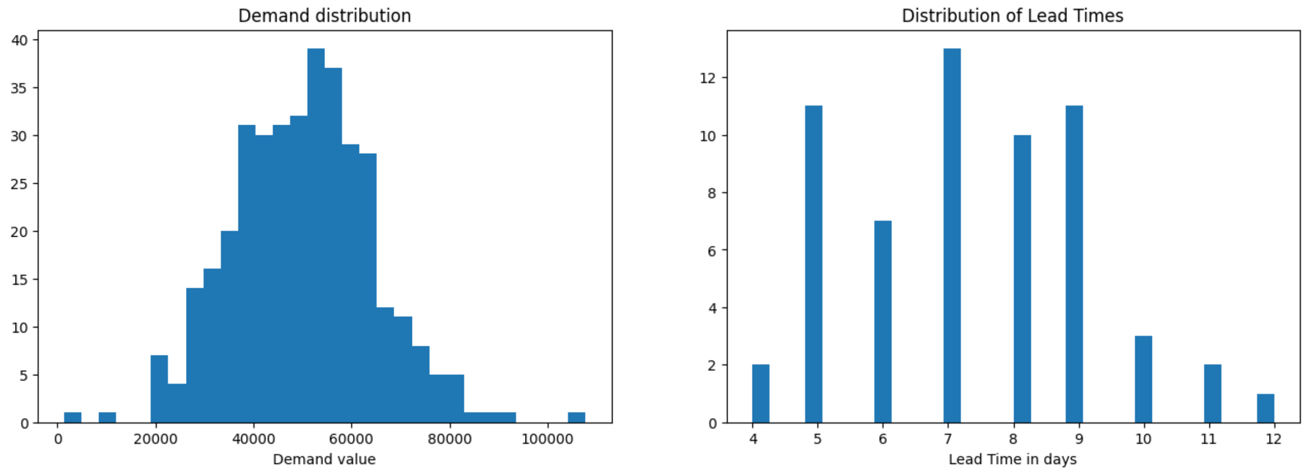

Figure 2: Demand and Lead-time distributions

3 First Proposed Policy

In this section, we will propose the solution for Level 1. We measure the performance of the last year, providing quantitative metrics. We are aware of the trade-off involved: having excessive stock is undesirable, but running out of stock and causing delays for customers is also unfavorable. With this solution as stated above we want to smoothen out the stock to minimize holding inventory costs as well as minimize potential backorder costs. As a part of our solution, we propose using Periodic Review Model:

$$TC = D \cdot C + \frac{D}{Q} \cdot S + \frac{Q}{2} \cdot H \rightarrow min \tag{2}$$

As a result of this minimization problem, we get the optimal EOQ (Economic Order Quantity):

$EOQ^* = \sqrt{\frac{2D \cdot S}{H}}$ - optimal quantity to reorder at one time
$T^* = \frac{EOQ^*}{D}$ - review time
$M^* = D \cdot (T^* + LT) + z_\alpha \sqrt{(T^* + LT) \cdot \sigma_d^2 + D \cdot \sigma_{LT}^2}$ - maximum amount of stock

Since 95% level is desired $z_{0.95} = 1.6449$. This is a necessary critical value to ensure that 95% of the time demand is satisfied.

As a result, the proposed strategy works as follows:

- Find optimal review time T^*
- Find the Maximum value of the stock with safety stock M^*
- Every T^* number of days check the stock and order M - current stock amount of stock

This way we will be able to smoothen out the amount of stock as well as minimize the risks of having backorders. In order to build the model we will use historic data. To backtest the proposed model we ran the model multiple times on the same demand sample. This way we were able to compare the previous strategy to our proposed one. As a result, we got the following:

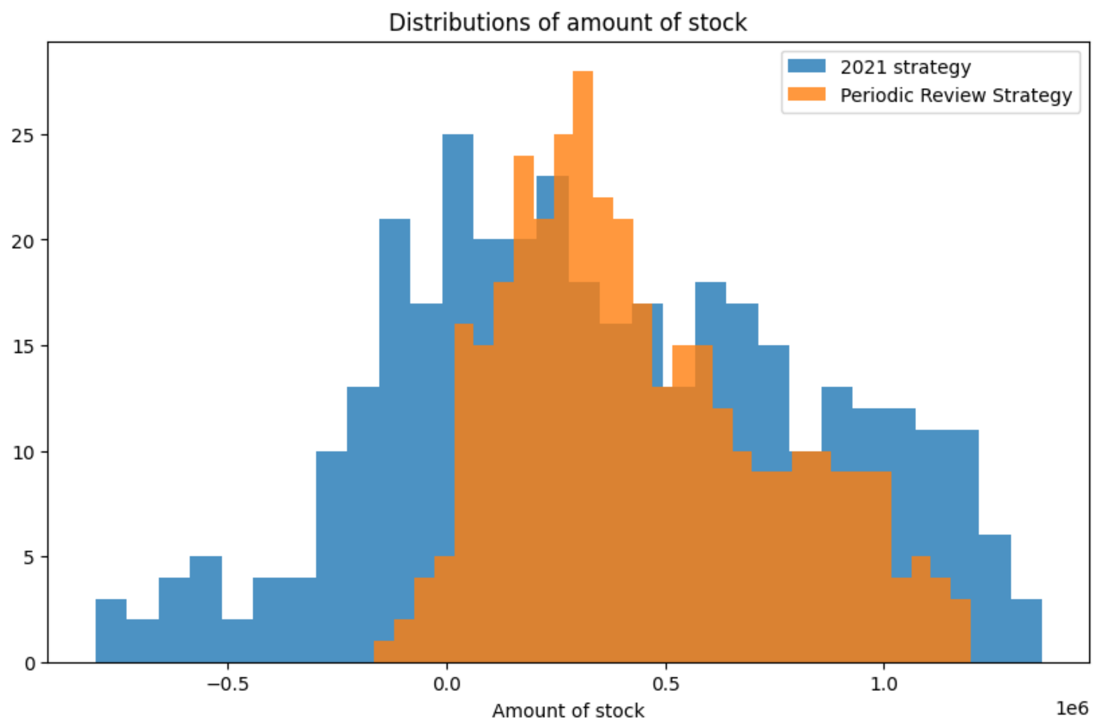

Figure 3: Distributions of the amount of stock

As we can see from the Figure (7) by implementing this strategy we were able to reduce the number of backorders ensuring a high service level of 95%. To get these results we are required to know both inventory costs and replenishment costs since these are deciding factors for finding an optimal policy. To provide you with some idea how this would like. We assumed that, S = 1000000 - reordering cost (one-time fixed cost), H = 1 - daily holding cost per unit, B = 100 (backorder cost per unit).

Provided the entry numbers above our strategy is on average 75 % more efficient (in terms of cost reduction) and still we are able to provide a high service level of around 98%. (Result may vary if we change the entry numbers such as costs but they are more or less the same)

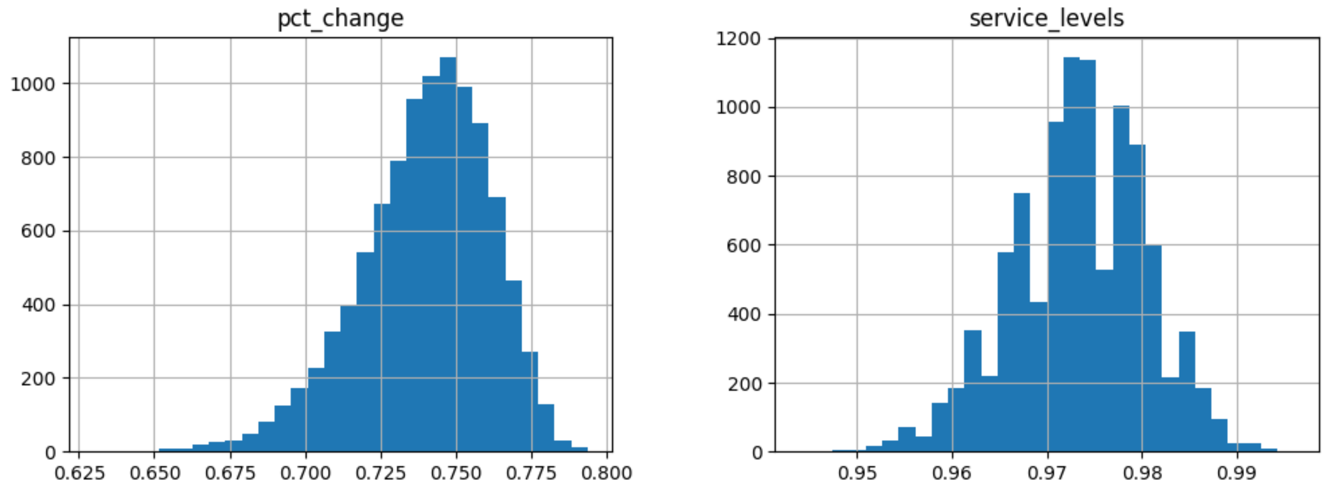

Figure 4: Distribution of cost reduction

4 Second Proposed Policy

Now we have to account for the fact that we can not order less than 500000 units of stock from the supplier. The procedure remains the same but we adjust it slightly to meet this new piece of information.

- Find optimal review time with the same formula as before T^*
- Find the Maximum value of the stock with safety stock M^*
- Every T^* number of days check the stock and order M - current stock amount of stock **only if it exceeds 500000** otherwise check next day

By implementing Period Review Policy with minimum order size we ensure high amounts of safety stock but this seems to come at a cost of potentially higher inventory costs. But in this case, we get no backorder costs, which ensures a 100 % service level at all times.

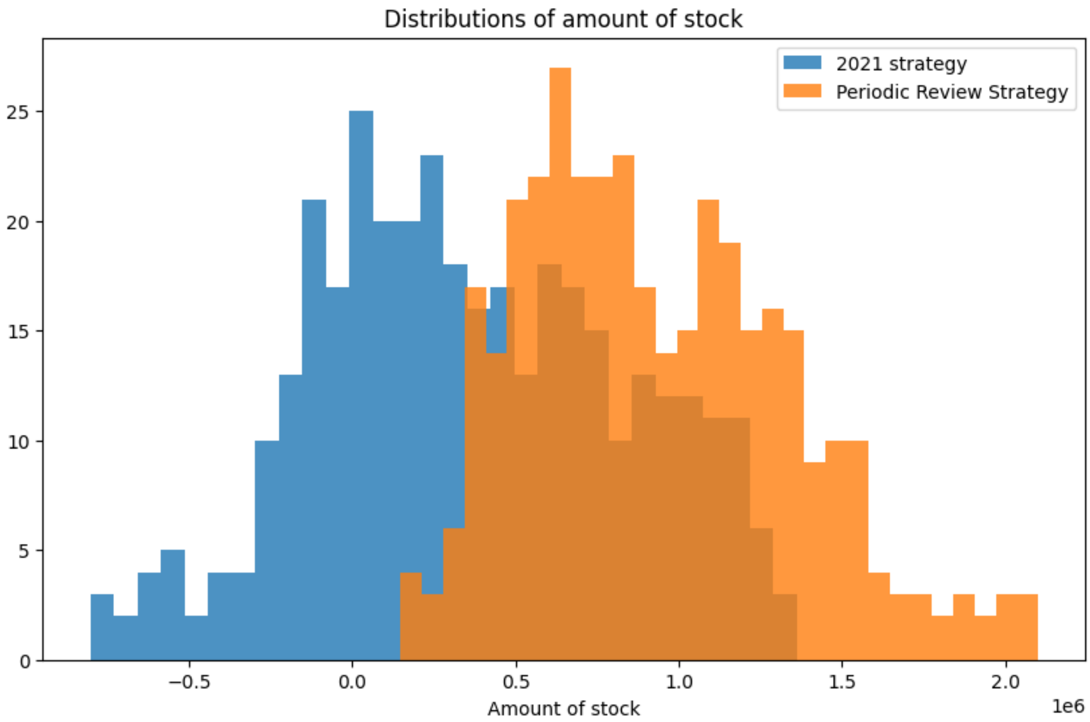

Figure 5: Distributions of the amount of stock

By introducing a minimum reorder size we are losing on potential gains from implementing our strategy. Below is the figure showing the distribution of the percentage saved from the costs of the original strategy.

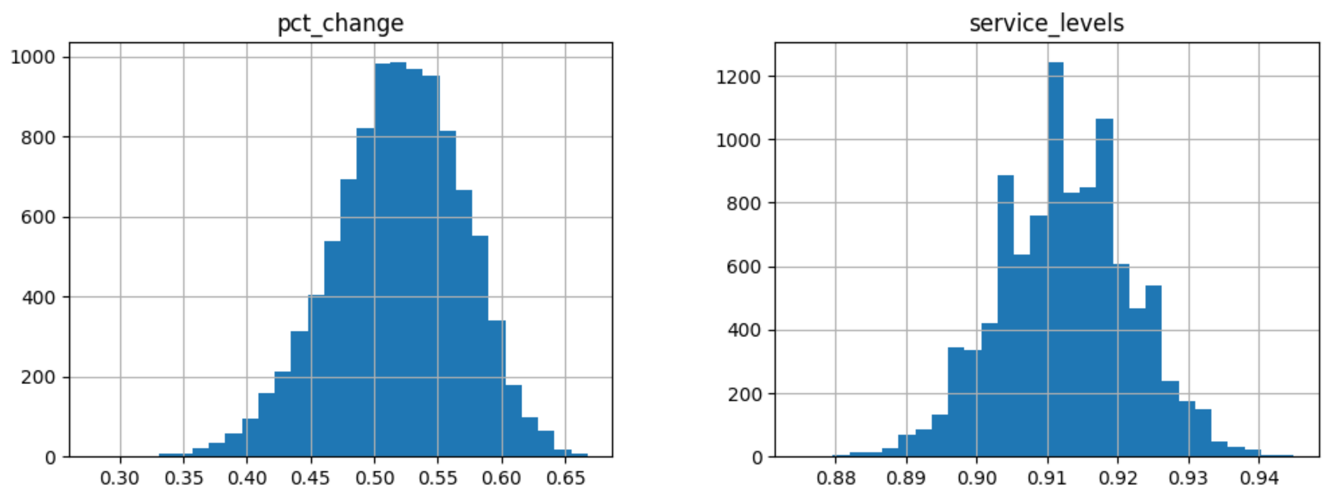

Figure 6: Distributions of cost reduction

As we see above, an average reduction in costs dropped by 50% which is still a great result. We are also able to provide a relatively high service level of 92%.

5 Choosing optimal Lead-Time

To choose the optimal Lead-Time we should compare how on average each one performs in terms of cost-reduction percentage.

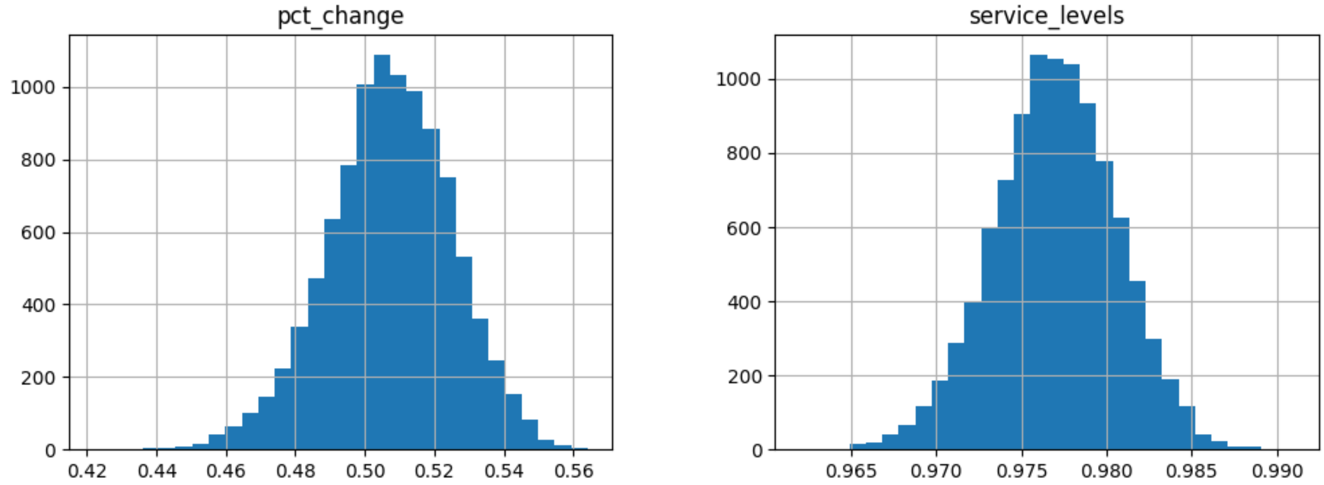

Figure 7: Distributions of cost reduction

From the distributions above we see that on average we lose by implementing a fixed Lead-Time of 14 days. Mainly this is due to the fact of increasing holding costs since we have to have more stock to go for longer periods of time between resupplies. But this is decided by initial entry variables such as inventory costs, backorder costs and resupply costs.

Table 2: Choosing optimal leadtime

	pct_change_14d	pct_change_7d
mean	0.507	**0.519**
std	0.018	**0.051**
min	0.422	0.280
25%	0.496	0.486
50%	0.507	0.521
75%	0.519	0.555
max	0.564	0.668

As we see 7 day lead-time results in higher cost reduction but higher variance in the cost-reduction whilst 14 day lead-time allows to have more stable gains of implementing our proposed policy but the gains themselves are smaller.