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Inventory management concepts and techniques

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Abstract: Inventory management has become one of the key elements of the supply chain management and can greatly affect the performance of a business. The textile industry is no exception. Traditional approaches in decision making based on manager instincts and hunches are no longer enough in the today's increasingly competitive environment. Small to medium sized family owned textile businesses are usually prone to this way of thinking.
This paper discusses some basic concepts and techniques for classifying inventory, controlling inventory levels, avoiding stock outs and increasing customer satisfaction. It also discusses the importance of forecasting demand and uses the Root Mean Square Error (RMSE) as an effective measure of the forecast error, which later becomes a basic driver for inventory management. It addresses the Service Level (SL) as a performance metric and emphasizes on the importance of Safety Stock (SS). Finally, it discusses the use of the Reorder Point (ROP) as an efficient indicator for triggering production replenishment and proposes a simple technique for prioritizing production orders.

1. Introduction

Inventory management is the process of monitoring and controlling inventory level and ensuring adequate replenishment in order to meet customer demand. Determining the appropriate inventory level is crucial since inventory ties up money and affects performance. Having too much inventory reduces the working capital and impacts the company's liquidity. On the contrary, having too little inventory leads to stock outs and missed sales which leads to less profit. It becomes clear that management attention should be focused on keeping inventory level somewhere in between, striving for increased customer satisfaction and minimum stock outs while keeping inventory costs as low as possible.

2. Service Level

The Service Level (SL) is an important performance indicator which in a simplified manner, measures a company's ability to service customer demand and is expressed as a percentage. In inventory management, service level is the probability that the customer demand is met or that the customer demand does not exceed the inventory. A service level of 95% means that there is 95% probability that demand will be met and customer orders will be fulfilled on time, while the probability that a stock out will occur, resulting in missed sales, is 5%.The higher the Service Level, the higher the customer satisfaction but also the higher the inventory level. Since the future demand is uncertain, achieving a 100% Service Level would require an infinite amount of inventory which is clearly unachievable. Management should understand the trade-off between the cost of inventory and the cost of stock-outs and position against inventory levels based on specific criteria.

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3. Inventory Classification

ABC inventory classification is a very popular inventory control technique that follows the Pareto Principle which states that, for many events, roughly 80% of the effects come from 20% of the causes. In a case of a business, it could be stated that roughly the 20% of the end products generates the 80% of the income. In ABC analysis, a company reviews its inventory and sorts all items into three categories, called "A" items, "B" items and "C" items. A typical breakdown would possibly describe “A” items as those that produce 70% of income, “B” items as those that produce 25% of income and “C” items, as those that produce 5% of income. This classification might be different from company to company but managers should be able to find the pattern that suits best their needs.

Clearly, “A” items require closer attention and should be handled differently. Assigning higher Service Levels for those items is a wise choice. The higher service level will lead to higher inventory but will also decrease the probability of a stock out. A 5% probability of a stock out for an “A” item will result to much higher losses than of a 5% probability for a “C” item. A 99% Service Level for an “A” item could have about the same impact as an 85% Service Level for a “C” item and managers should position against each category accordingly.

4. Forecast Error and Safety Stock

It has been already stated, that customer demand is uncertain. Managers should try to predict future demand based on statistical data and taking into account multiple criteria. It is highly desirable to try to predict the future demand and get properly prepared even with a certain degree of uncertainty than having no expectation of what is about to happen. The methods and tools used for forecasting are not under the scope of this paper. What is really important, is to find a way to calculate how closely the prediction of the demand meets the actual demand, thus how accurate a forecast is. The difference between the actual and the forecasted data is the Forecast Error.

Since the Forecast Error can be calculated and not just predicted, it can be quite a safe driver for inventory management. The goal is to keep just as much inventory as it is really needed and by knowing that there is a fixed error in our estimation, we can safely take it into account and add up a bit of extra stock to our inventory to compensate for this misalignment. This is called Safety Stock and its purpose of existence is to absorb the error of the estimation and to protect the company against an unexpected and unwanted stock out. In a simplified scenario, a 30% variation of the forecasted demand should result in a 30% increase of the inventory level.

5. Root Mean Square Error (RMSE)

In order to calculate the errorof a forecast the RMSE method is preferred among others, as it calculates the standard deviation of the residuals between the actual and the forecasted data. As the name suggests, the difference between the forecasted demand and the actual demand is squared and then it is expressed as the square root of the average squared residuals. In the table below, real data are presented.

Table 1. Calculation of the RMSE of the Forecasted Demand for SKU X

Month	Actual Demand	Forecasted Demand	Squared Error		Total Squared Error	Average Squared Error	RMSE
1	1.508	1.533	625		1.658.065	138.172	372
2	1.884	1.867	289				
3	1.024	1.234	44.100				
4	1.458	1.523	4.225				
5	2.433	2.763	108.900				
6	3.523	2.707	665.856				
7	2.322	1.998	104.976				

8	818	444	139.876
9	1.753	1.015	544.644
10	1.889	1.767	14.884
11	1.438	1.509	5.041
12	1.283	1.440	24.649

The reader will quickly realize that the forecasted data are not highly accurate. Although forecast accuracy is important, it will soon become clear that calculating the forecast error and taking itinto account when positioning against inventory levels is more significant than the accuracy of the forecast itself, when our primary concern is to protect against stock outs.

6. Mixing Service Level, Safety Stock and RMSE

When the desired Service Level for a stock keeping unit (SKU) is selected and the RMSE of the forecast has been defined then the Safety Stock can be accurately calculated. The SKU in table 1 was classified as an “A” item and the Service Level was set to 97%. Under the assumption that our data are following a normal distribution curve, then in 97% of the cases, the actual demand will be less than 1,88 standard deviations above the mean demand (see appendix A).

Any sample value will lie within $\mu \pm \sigma \times Z$. Since we are looking only for extra stock we actually calculate only for $\mu + \sigma \times Z$. In addition, we know our estimation’s variance but we need to calculate the variance during the lead time. The safety stock needed during the manufacturing lead time can be calculated using the following formula:

$$Safety\ Stock = Z \times \sqrt{LT} \times RMSE$$

Where:

Z =Z-score for the desired Service Level (see appendix A)
LT = The Lead Time using in the same time period as in the forecast
RMSE = The Root Mean Square Error between the actual and the forecasted demand

Table 2. Parameters for SKU X

RMSE	372
Service Level	97%
Working Days per Month	22
Manufacturing Lead Time (Days)	5
Z Statistic	1,88

Given the data from table 2, the Safety Stock for SKU X can be calculated as below:

$$Safety\ Stock = 1{,}88 \times \sqrt{\frac{5}{22}} \times 372 = 333\ units$$

Thus, keeping 333 units of extra stock for SKU X, will prevent a stock out for 97% of the time.

One could note that in the textile industry, the manufacturing lead time is also been subjected to a certain variance. This can be due to the irregular machine cycle time or due to an unexpected downtime of the machinery. For instance, the setup time of a stenter machine is greatly affected by the process it previously underwent resulting in extra time for heating it up or cooling it down. It is wise to take this variance under consideration and adjust the lead time in the equation accordingly. If the variance of the demand and the variance of the lead time are independent of each other,then the safety stock is Z-score times the square root of the sum of the squares of the individual variabilities, as in the following equation:

$$Safety\ Stock = Z \times \sqrt{(LT \times RMSE_D)^2 + (RMSE_{LT} \times \overline{D})^2}$$

But if both the variance of the demand and the variance of the lead time are dependent of each other then safety stock can be computed as below:

$$Safety\ Stock = Z \times \sqrt{LT} \times RMSE_D + Z \times RMSE_{LT} \times \overline{D}$$

Where:

Z = Z-score for the desired Service Level (see appendix A)
LT = The Lead Time using in the same time period as in the forecast
$RMSE_D$ = The Root Mean Square Error between the actual and the forecasted demand
$RMSE_{LT}$=The Root Mean Square Error between the actual and the standardlead time
$\overline{D}$= The average forecasted demand

Table 3. Parameters for SKU X

$RMSE_D$	372
Service Level	97%
Working Days per Month	22
Manufacturing Lead Time (Days)	5
Z Statistic	1,88
$RMSE_{LT}$ (Days)	0,25 (6 hrs)
Average Forecasted Demand (monthly)	1650

Given the data from table 3, the safety stock can be calculated. It was decided that the variance of the lead time and the variance of the demand was dependent of each other. This is quite typical in textile factories since the life expectancy of the industrial machinery is very high (many decades) and as a result, new machinery with higher output rate is added before old machinery is regarded obsolete and its use is been discontinued. Thus, when demand rises and extra capacity is needed, managers decide to add shifts and make use of old and new machines simultaneously which produce the same products at different output rates resulting in higher variance in the manufacturing lead time. Taking this into account, the Safety Stock is calculated below:

$$Safety\ Stock = 1{,}88 \times \sqrt{\frac{5}{22}} \times 372 + 1{,}88 \times \frac{0{,}25}{22} \times 1650 = 369\ units$$

Thus, keeping 369 units of extra stock for SKU X, will prevent a stock out for 97% of the time.

7. The Re-Order Point

The Re-Order Point (ROP) technique is a process of triggering inventory replenishment based on inventory level. The ROP is set at a level which is calculated based on the forecasted demand during the replenishment time plus a safety stock, as in the following equation:

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$$ROP = \overline{D} \times \overline{LT} + SS$$

Where:

$\overline{D}$= The average forecasted demand
$\overline{LT}$= The average Lead Time
SS = The Safety Stock

Keeping the same data as before, the ROP for SKU X is calculated below:

$$ROP = \frac{1650}{22} \times 5 + 369 = 744\, units$$

Thus, the inventory level of SKU X should be closely monitored and as soon as it becomes equal or less than 744 units, then production should be reinitiated. There should be just enough time to reproduce the item before its inventory level reaches the safety stock level but even if it does there will be 97% chance that the safety stock will be enough to protect against an unexpected customer demand or a production delay and only 3% chance that the inventory level will fall to zero and a sales order will not be satisfied on time.

There will also be times when the accumulated pending orders will exceed the inventory level even before the ROP is reached. Thus, the future fulfilment of the pending orders will probably lead to a stock out. Clearly, the Projected Inventory level is of concern and it is calculated according to the formula bellow:

$$Projected\ Inventory = \ Stock\ On\ Hand + WIP - Pending\ Orders$$

Where:

Stock On Hand = The available inventory
WIP = The inventory that is already in process but not yet finished (Work in Process)
Pending Orders = The pending orders that are due today or already past due

Based on the above approach, production should be initiated whenever the Projected Inventory level falls below the ROP.

8. Prioritizing Production Orders

In real life, the inventory or the projected inventory level of multiple stock keeping units will simultaneously reach or fall under their ROP. There are also capacity constraints or other constraints that force managers to perform some kind of prioritization of the production. When avoiding a stock out is the primary concern, then some of the key elements for deciding how to prioritize production are: the ABC classification, the Inventory Turnover Ratio and the Projected Inventory Level.

The Inventory Turnover ratio is metric that calculates the number of times that inventory cycles (turns) during a given period. It is calculated as the Cost Of Goods sold over the average inventory but can also be expressed as the number of units sold over the average number of units. The importance of the ABC classification and the Projected Inventory Level has already been discussed.

The following excel sheet depicts a real life situation:

Table 4. Excel Inventory Report

Code	WIP	Stock	SS	ROP	Pending Orders	ABC Rating	Inv. Turnover	Projected Stock	Status
SKU2463		260	102	194	756	C	4	< 0	🔴
SKU2794		296	88	167	32	C	4	>ROP	🟢
SKU2854		300	75	143	280	C	2	<=SS	🔴

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Code	**WIP**	**Stock**	**SS**	**ROP**	**Pending Orders**	**ABC Rating**	**Inv. Turnover**	**Projected Stock**	**Status**
SKU1282		910	370	681	51	B	6	>ROP	🟢
SKU1362	600	800	502	871	900	A	7	<=SS	🔴
SKU2341		778	88	167	350	C	2	>ROP	🔴
SKU2361		1.001	292	537	450	B	5	>ROP	🟢
SKU2461	600	1.082	419	725	960	A	8	<=ROP	🔴
SKU2791		1.618	923	1.600	253	A	12	<=ROP	🔴
SKU2851		780	641	1.111	858	A	7	< 0	🟢

The Status becomes green and signifies the need for production when the projected inventory level falls below the ROP. SKU2851 & 2463 have not enough stock to fulfil the pending orders thus their production should be prioritized. SKU1362 & 2854 will soon fall under their safety stock level thus they should be produced right after. SKU2461 & 2791 will soon fall under their ROP but SKU2791 cycles a bit faster than 2461 thus it would be wiser to produce it first.

The idea behind it is to prioritize those items that their projected stock falls below zero. If more than one item meets this rule then prioritize based on their ABC classification. If again more than one item meets this rule then prioritize based on their turnover ratio. Then check for all the items that their projected inventory will fall under their safety stock level prioritizing them the same way and finally check for those items that their projected inventory level that will fall under their ROP.

9. Conclusions

This paper emphasizes on the importance of inventory management. The methods and tools that are used can add great business value. Holding the right amount of inventory can increase business performance by reducing the response time to customer demand which results to higher customer satisfaction. The textile managers and business owners should weigh and balance the trade-offs when deciding how much inventory to hold and strategically decide based on the proven concepts and techniques that are described.

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Appendix A

Normal Curve Areas
Standard normal probability in right-hand tail

	Second decimal place of z									
z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014

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