Safety Stock comparison with Availability and Service level

Nick T. Thomopoulos
IIT Stuart School of Business
Illinois Institute of Technology
565 W. Adams St., Chicago, IL 60661
Phone: 312-906-6536, thomop@stuart.iit.edu

This paper gives a comparison between two fundamental methods of determining the safety stock. The methods are denoted as Availability and Service Level. Tables that compare the methods are provided and list how much safety stock in month's supply is needed for typical situations.

Two common methods to determine the size of the safety stock are the availability method and the service level method. The desired *availability* (denoted as AV) becomes AV = probability of not running out of stock during the lead time. The desired *service level* (denoted as SL) is typically measured as SL = (demand filled) over (total demand). The safety stock is the stock carried to meet the uncertainty associated with the forecasts of the demands. The uncertainty in demands is a measure of the forecast error. The typical measure of the forecast errors is the standard deviation of the one month ahead forecast error and is denoted here as σ.

The difficulty in the above statements is that oftentimes it is confusing which method is being applied to generate the safety stock. The term service level is the most common, followed perhaps by availability and percent fill. In the above definitions, the measure of *availability* is a probability and the measure of *service level* is a ratio falling between zero and one. Although both methods of finding the safety stock yield different results -- it is noted in many references -- the term service level is often the only term used for both of the methods. That is, the definition given above for availability is often referred as the service level. Sometimes the term *percent fill* is used in place of the service level. For convenience in this paper, the terms availability and service level are used in the following way:

availability = probability of (not out of stock during the lead time)

service level = ratio of (demand filled / total demand)

Percent fill may be substituted in place of the service level. Using either method, ss demotes the safety stock, F_L the lead time forecast and op the order point. Thereby,

$op = F_L + ss.$

Safety stock from Availability

References [1],[4] show how to compute the safety stock to yield the *availability* goal set by the management. Reference [1] uses the term service level and [4] uses availability. On an individual part, the data used to determine the safety stock is listed below:

AV = availability
L = lead time to procure the part from the supplier
σ = the standard deviation of the one-month ahead forecast error

Availability is a statistical measure taken from the normal distribution called the cumulative probability distribution and generally denoted as F(k) where k is the safety factor. Thereby, AV = F(k). Below lists the values of k that corresponds with a common set of F(k) entries.

F(k)	.900	.925	.950	.975	.990
k	1.2817	1.4398	1.6452	1.9604	2.3268

The standard deviation over the lead time is $\sigma_L = \sqrt{L}\ \sigma$ and thereby the safety stock to yield the availability is simply $ss = k\sigma_L$

For the analysis of this paper, references [3], [4] show how the forecast error is converted in units of the average monthly forecast (F) as shown below:

$cov = \sigma/F$ = coefficient of variation

This way, the data is independent from the forecast size and is defined in relative terms. The data to determine the months of safety stock is now reduced to the following:

AV = availability
L = lead time in months
cov = coefficient of variation

So now the safety stock to yield the desired availability is computed as follows:

$ss = k\sqrt{L}\ \sigma = k\sigma_L$ (pieces)

where k (the safety factor) associated with F(k) = AV is used. In month's supply the safety stock is obtained from:

$ss = k\sqrt{L}\ cov$ (months)

Safety stock from Service Level

References [2], [3], [4] show how to compute the safety stock to yield the service level goal as desired by the management. On an individual part, the data used to determine the safety stock is listed below:

SL = desired service level
F = average monthly forecast
L = lead time to procure the part from the supplier
Q = the size of the order quantity
σ = the standard deviation of the one-month ahead forecast error

For the analysis of this paper, references [3], [4] show how the order size and forecast error are converted in units of the average monthly forecast, as shown below:

$M = Q/F$ = months-in-buy
$cov = \sigma/F$ = coefficient of variation

This way, the data is independent from the forecast size and is defined in relative terms. The data to determine the months of safety stock is now reduced to the following:

SL = desired service level
L = lead time in months
M = the order size in months supply
cov = coefficient of variation

The safety stock is determined as follows:

$$ss = k\sqrt{L}\ \sigma = k\sigma_L \qquad \text{(pieces)}$$

where k is the safety factor associated with $E(k) = (1\text{-}SL)Q/\sigma_L$ (the partial expectation). In month's supply, the safety stock it is obtained from:

$$ss = k\sqrt{L}\ \text{cov} \qquad \text{(months)}$$

Table comparisons

Reference [4] gives a series of tables that list the months of safety stock for a wide variation of service level situations using the data above. Three tables of this paper list some of the results from the reference. The tables are arranged as follows:

Table 1. L = 0.25 (one week) and M = .50 (one-half month)
Table 2. L = 1.00 (one month) and M = 1.00 (one month)
Table 3. L = 2.00 (two months) and M = 1.00 (one month)

Each of the tables give safety stock results (in month's supply) from six values of availability (AV = 0.900, 0.925, 0.950, 0.975, 0.990), six values of the service level: (SL = 0.900, 0.925, 0.950, 0.975, 0.990), and five values of the coefficient of variation (cov = 0.1, 0.3, 0.5, 0.6, 0.8 and 1.0). Note the tables are split into two sections: upper and lower sections.

The upper section lists the months of safety stock needed to yield the availability goals and the lower section lists the safety stock to yield the service level goals.

Summary

This paper shows how much safety stock is needed by two common methods. First is when management's goal is stated as an availability (denoted as AV), and the second is when the goal is stated as a service level (denoted as SL). The tables of the paper list how much safety stock is needed with each method. In all situations, the tables show that more safety stock is needed when management chooses the availability criterion rather than the service level criterion.

References

1. Arnold, J.R.T., *Introduction to Materials Management*, Englewood Cliffs, NJ. Prentice Hall, Inc., 1998.

2. Brown, R.G., *Smoothing, Forecasting and Prediction of Discrete Time Series*, Englewood Cliffs, NJ. Prentice Hall, Inc., 1962.

3. Thomopoulos, N.T., *Applied Forecasting Methods*, Englewood Cliffs, NJ. Prentice Hall, Inc., 1980.

4. Thomopoulos, N.T., *Strategic Inventory Management and Planning*, Carol Stream, Il. Hitchcock Publishing Company, 1990.

Table 1. L = .25 and M = .50
Months of safety stock vs. lead time, months-in-buy, coefficient of variation, availability and service level

---

----months----			----------AV----------				
L		cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
0.25		0.10	0.06	0.07	0.08	0.10	0.12
0.25		0.30	0.19	0.22	0.25	0.29	0.35
0.25		0.50	0.32	0.36	0.41	0.49	0.58
0.25		0.60	0.38	0.43	0.49	0.59	0.70
0.25		0.80	0.51	0.58	0.66	0.78	0.93
0.25		1.00	0.64	0.72	0.82	0.98	1.16

----months----			----------SL----------				
L	M	cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
0.25	0.50	0.10	0.00	0.00	0.00	0.02	0.04
0.25	0.50	0.30	0.02	0.05	0.09	0.15	0.22
0.25	0.50	0.50	0.12	0.17	0.22	0.31	0.42
0.25	0.50	0.60	0.18	0.23	0.30	0.40	0.52
0.25	0.50	0.80	0.31	0.37	0.46	0.59	0.74
0.25	0.50	1.00	0.45	0.53	0.63	0.78	0.97

Table 2. L = 1 and M = 1
Months of safety stock vs. lead time, months-in-buy, coefficient of variation, availability and service level

---

----months----			----------AV----------				
L		cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
1.00		0.10	0.13	0.14	0.16	0.20	0.23
1.00		0.30	0.38	0.43	0.49	0.59	0.70
1.00		0.50	0.64	0.72	0.82	0.98	1.16
1.00		0.60	0.77	0.86	0.99	1.18	1.40
1.00		0.80	1.03	1.15	1.32	1.57	1.86
1.00		1.00	1.28	1.44	1.65	1.96	2.33

----months----			----------SL----------				
L	M	cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
1.00	1.00	0.10	0.00	0.00	0.00	0.03	0.09
1.00	1.00	0.30	0.04	0.10	0.18	0.30	0.43
1.00	1.00	0.50	0.24	0.33	0.45	0.63	0.83
1.00	1.00	0.60	0.36	0.47	0.60	0.80	1.04
1.00	1.00	0.80	0.62	0.75	0.92	1.18	1.48
1.00	1.00	1.00	0.90	1.05	1.25	1.57	1.94

Table 3. L = 2 and M =1
Months of safety stock vs. lead time, months-in-buy, coefficient of variation, availability and service level

---

----months----			----------AV----------				
L		cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
2.00		0.10	0.18	0.20	0.23	0.28	0.33
2.00		0.30	0.54	0.61	0.71	0.83	0.99
2.00		0.50	0.91	1.02	1.16	1.39	1.65
2.00		0.60	1.09	1.22	1.40	1.66	1.97
2.00		0.80	1.45	1.63	1.86	2.22	2.63
2.00		1.00	1.81	2.04	2.33	2.77	3.29

----months----			----------SL----------				
L	M	cov	0.900	0.925	0.950	0.975	0.990
----------			----------ss----------				
2.00	1.00	0.10	0.00	0.00	0.01	0.08	0.15
2.00	1.00	0.30	0.16	0.24	0.34	0.50	0.68
2.00	1.00	0.50	0.50	0.61	0.77	1.00	1.27
2.00	1.00	0.60	0.69	0.82	1.00	1.27	1.59
2.00	1.00	0.80	1.09	1.26	1.48	1.83	2.24
2.00	1.00	1.00	1.53	1.73	2.00	2.42	2.92
