SERVICE LEVEL AND SAFETY STOCK BASED ON PROBABILITY

Stuart Wilkinson, REL Consultancy Group

PROLOGUE

From our experience in working on stock reduction for the last 20 years, we were very interested in Mr Burgess's article 'Safety Stocks or How to Manage an Inefficient Business' (Control November 1995).

Time and time again there is the challenge of 'safety stock' and we have found that more often than not it has been the experience of the materials planner to use 'gut feel' to set the level of safety. However, we have helped many clients rectify this by implementing mathematical models to calculate the levels of safety stock required. This often led to re-definition of stock management policies.

Lack of stock policies leads to inconsistent service levels offered and a lower average service level overall. It is surprising how many large blue chip companies do not have stock policies in place and rely on local management knowledge and skill to maintain the levels of stock necessary, often to poorly defined service level requirements. Stock will not reflect the volume and variability in demand for individual products, and consequently total stocks tend to be high.

In the last few years, we have worked for over 30 clients, in excess of 90% of these did not set mathematically based safety stock levels (most did not have a stock management policy). Of those that were using statistical calculations to determine their required safety stock levels, in the main, they were only doing so because the software they were using required key parameters in order to function. This can lead to the senior management not understanding the methodology and consequently the service level policy may be flawed.

Defining the level of service that is to be offered is not an easy task for any business. It is all very well setting a service level target, but the business needs to know the cost of stock related to that service. This question is very difficult to answer without a structured approach to stock management. A stock model based on statistical safety stock calculations can help target the service level that the business can afford.

STRUCTURED APPROACH TO STOCK MANAGEMENT

Certainly, a systematic approach to managing stock always beats 'gut feel' and sole reliance on local experience. We assume that historical demand patterns can be used to calculate the level of safety stock required to offer a level of service. We make the assumption that the forecast error is normally distributed, which then allows us to apply proven statistical techniques to calculate safety stock levels.

Our clients frequently raise questions about using this method but we have found that irrespective of volume and variability it is valid to assume a normal distribution. As practical implementing consultants, over the years we have developed stock models using statistical techniques that have realised significant stock reduction (or service increase) benefits to all our clients.

Once the service level is defined, the safety stock for each item can be calculated. This should be done regularly using recent demand and forecasting history to ensure that the correct safety level is used and supplements any stock controlling systems already in place.

SAFETY STOCK

Method of safety stock calculation. Safety stock is a buffer against any uncertainties that exist in the supply chain. If no forecasts are made then safety is required to buffer the variability in demand. However, if forecasts of demand are available then the safety stock will only be required to buffer the variability in forecast error. Any other identifiable variabilities, such as supplier lead time, should be catered for within the safety stock, to provide the required service. For the purpose of this article, we shall only deal with variabilities in forecast error.

Customer service is a measure of the probability of supplying a customer requirement. The service level definition I shall use is referred to as 'cycle-service level' [1], the percentage of cycles where there will not be shortages. There are other measures of customer service that can be used, such as 'line fill' and 'lost sales', but we are not going to deal with them here . A 95% 'cycle-service level' means a 0.05 probability that demand cannot be met during the lead-time cycle for the product.

The safety stock calculation [1] assumes a normally distributed forecast error over unit time and a constant lead time:

Safety Stock = Z x (standard deviation of forecast error) x square root of the lead time

where Z is the number of standard deviations from the mean corresponding to the service level required, i.e. 98% service level equates to a probability of demand greater than the safety stock of 0.02 and 0.02 probability from Normal distribution tables gives Z = 2.05

and 'lead-time' is defined as the length of time it takes to replenish stock and is required to adjust the forecast error to cater for how far ahead we have to look when deciding what to make (or buy). It is measured in the units of the time period that the safety stock is being calculated in, lead time is expressed in weeks for calculations done in weekly periods.

In practice the safety stock calculation uses historic demand data, the number of periods being a compromise between sufficient data points and recent enough 'history' to be relevant. Sensitivity tests are recommended.

When we do this calculation we do not want an absolute level based on history to be used as the future safety stock. Therefore it is recommended that all calculations are normalised into Days-of-Sale (DoS). An average historic demand can be used to convert the forecast error into DoS before calculating the safety stock. The number of units of safety stock can then be determined by multiplying the safety stock in DoS by the expected daily demand (ie. average current forecast).

EXAMPLES

For the examples I have extracted some actual demand and forecast data from our client database. Figure 1 shows a typical set-up of an operational spreadsheet. Week number 8 is the current week and the start of safety stock calculation, using 8 weeks of historic forecast error. Note the service level has been set to 98% (resulting safety stock will limit the probability of stock-outs to 0.02 on average).

I have set the lead time to 1 week for simplicity, though it is interesting to note that the safety stock is proportional to the square-root of the lead-time, ie. if it takes 2 weeks to replenish stock then the safety increases by 41%.

The calculations are normalised in terms of DoS. I have also put in a check line (row 15) showing the *'mean absolute deviation'* over *'standard deviation'* for the forecast error - a true normal distribution has a value of 0.8, comparable to the distribution of the actual data used in the example.

To show how much the required level of safety can change, but offering the same service, we need to move on a few weeks. Figure 2 shows another product, Product 2, being analysed in basically the same spreadsheet, but now the current week is number 12.

The safety is calculated the same way each week using a rolling 8 week history of forecast error, a constant lead time and constant service level. However, the actual safety level changes, quite substantially, and not necessarily in proportion to the demand. I make the last point because many stock management systems set parameters in terms of DoS or weeks of sale, simulated in Figure 2 by calculating the stock level equivalent to 1.5 DoS. Comparison with the statistically calculated safety prompts us to consider the benefits in using this kind of spreadsheet model to regularly update any re-order point systems.

Figure 1

SAFETY STOCK SPREADSHEET - FIRST CALCULATION

A	A	B	C	D	E	F	G	H	I	J	K
2	**Week 8 Safety stock**										
3		Weeks	1	2	3	4	5	6	7	8	9
4					MAD / STD DEV =0.856			True Normal distribution =0.800			
5											
6	**Product**				Average DoS =1363						
7											
8	DEMAND:		6350	6250	8430	6500	5940	6960	6980	711	
9	FORECAST:		7080	7080	7420	6960	6960	6960	6960	6880	6880
10	Forecast error		-730	-830	1010	-460	-1020	0	20	230	
11		Standard deviation of forecast error over 8 weeks history								628	
12		Standard deviation in DoS								0.46	
13		Customer service level							Z =	2.05	
14		Lead-time to replenish stock							LT =	1.0	week
15		Safety stock in DoS								0.94	
16		Expected daily demand								1356	units
17		Safety stock based on expected demand								1280	units

Figure 2

SAFETY STOCK SPREADSHEET - FURTHER CALCULATIONS

B	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**Week 12 Safety stock calculation**														
2															
3		Weeks:	1	2	3	4	5	6	7	8	9	10	11	12	13
4	**Product 2**		MAD / STD DEV = 0.866				(weeks 1 to 8)			0.835	(weeks 5 to12)				
5	Lead-time =	1.00													
6	98% CSL, Z =	2.05			Average DoS = 1061										
7															
8	DEMAND:		4150	5980	7060	4230	4300	5120	5340	6270	5220	5300	5800	7250	
9	FORECAST:		6110	6110	6400	5420	5420	5420	5420	5820	5820	5820	5820	5820	7030
10	Forecast error		-1960	-130	660	-1190	-1120	-300	-80	450	-600	-520	-20	1430	
11		Standard deviation of forecast error over 8 weeks history								835	624	625	521	721	
12		Standard deviation in DoS (using avg. 8 weeks demand)								0.79	0.57	0.58	0.50	0.65	
13		Safety stock in DoS								1.61	1.18	1.20	1.03	1.33	
14		Expected daily demand (avg. forecast)								1164	1164	1164	1245	1240	
15		**Safety stock based on expected demand**								**1878**	**1369**	**1392**	**1279**	**1643**	
16															
17		**Safety based on fixed 1.5 DoS (rolling average)**								**1577**	**1646**	**1660**	**1694**	**1768**	

MORE ADVANCED CALCULATIONS AND THE TOTAL STOCK PICTURE

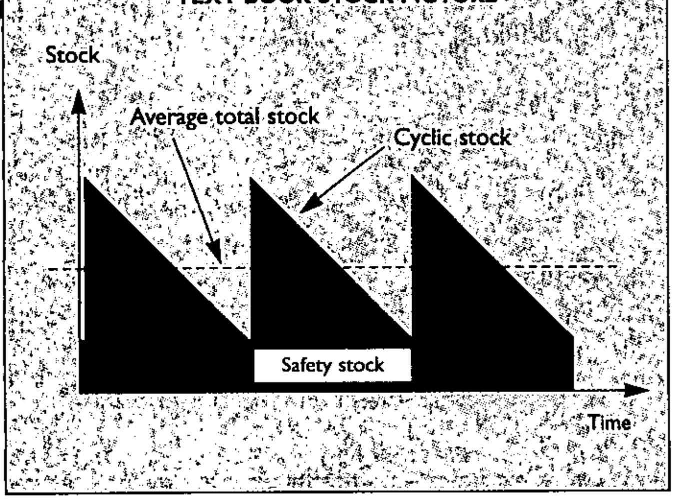
As already mentioned above, the safety stock calculations in the example spreadsheet, are the least complex that we use in stock modelling. Supplier lead time or delivery quantity can be measured and incorporated into the statistical model as errors to the plan. In a production environment actual output may vary from the schedule, either in quantity terms by receiving more/less than expected or in timing terms by receiving product too early/late. In these instances the safety stock needs to be adjusted in order to offer the service level targeted by the company.

Safety stock is just one element of the total stock. The other is often referred to as cyclic stock and is due to replenishment in batches. In our experience the cyclic stock is often greater than the safety stock and consequently needs careful examination in the light of overall stock reduction:

Total stock = safety stock + cyclic stock

Figure 3:

TEXT BOOK STOCK PICTURE



The total stock is therefore dependent on demand characteristics, service level offered and batching rules. A further step is possible that can make significant reductions in company's overall stock levels by recognising the interdependence between safety and cyclic stock. We have developed stock models which allow the batching rules to be changed to give significant reductions in the necessary safety stock level, and consequently reducing the overall total stock for the business [2].

REFERENCES:

[1.] Waters,CDJ . 'Inventory Control and Management', University of Calgary

[2.] Keaton, Mark H. 'A New Functional Approximation to the Standard Normal Loss Integral' Integrated Logistic Systems, BPICS, Production & Inventory Management, 2nd qtr 1994, Volume 35, Number 2.

About the Author

Stuart Wilkinson is a Consultant with REL Consulting Group, London. He graduated from Southampton University with a degree in Aerodynamics and joined Westland Helicopters in 1989. Involved with materials management and cellular manufacturing, Stuart was a production supervisor before joining REL. His work with REL has centred around stock modelling.