STATISTICAL FORECASTING

1. Introduction. This instruction will continue your education in the manipulation of numbers, which are so common in the world of inventory management. We want to do an in depth study of the moving average as it is used in the Commodity Command Standard System (CCSS) and give you an understanding of how it works. In order to do this, we will discuss precise and approximation numbers. We will look at them and understand the types of rounding methods used in the system. Finally, you will get an explanation and discussion of the moving average technique, the program change factor, and how we can validate this information.

2. Categories of Numbers. In inventory management, we deal with two categories of numbers. They are:

a. Precise Numbers. Some examples are number of days in a week; inches to a foot; unit prices; and number of supply control studies completed in a day by an item manager.

b. Approximations. Examples of appropriations are expected life of a repair part; shelf life of an item; and forecast average monthly demands. These approximations must be evaluated for validity and degree of accuracy. It must be remembered that the accuracy of this type of number depends upon the source and reliability of the basic data.

3. Rounding Methods. In many cases, the numerical result of a calculation will need to be simplified. For example, we may calculate the average demand rate for an item as 237.33. The number 237 is chosen because the fraction .33 is closer to being 0 than to being 1 and, therefore, 237.33 is closer to 237 than to 238. This process of reducing the digits in a number is called "rounding." There are three methods of rounding that can be used.

a. <u>Conventional Method</u>. This is the most widely known method of rounding. What do we do in the case where the fractional part is .5? For example, 84.5? If the conventional method is used, you round up to the next higher number (84.5 = 85) when the fractional portion is one-half or greater.

Digit to be rounded	1 2 3 4	5 6 7 8 9
	⟵	⟶
Direction of rounding	DOWN	UP

Notice that this method forces us to round up more often than down and introduces a bias.

b. <u>Always-Round-Up Method</u>. Regardless of the fractional portion, round up (84.2 = 85 or 84.001 = 85). <u>Always</u> round up.

Digit to be rounded	1 2 3 4 5 6 7 8 9
Direction of rounding	UP

c. <u>Round-to-Even Method</u>. In the situations above, the rounding of .5 is always up to the next higher number and there will be some degree of overstatement. If, on the other hand, the rounding was always down to the next lower number, there would be some degree of understatement. A balance between these alternatives is the "round-to-even" method. If the whole number portion is even, round down (8<u>4</u>.5 = 84). If the whole number portion is odd, round up (8<u>5</u>.5 = 86). That is, in any case where the fractional portion is exactly one-half, round to the nearest even number. This method has the effect of rounding up about half the time and rounding down about half the time. Thus, it is not biased.

Digit to be rounded	1 2 3 4	5	6 7 8 9
	⟵		⟶
Direction of rounding	DOWN	TO EVEN NUMBER	UP

(1) The "round-to-even" method is widely used in business accounting firms and has proven to be more consistent than either the

conventional or “always-round-up” methods. CCSS calculations normally carry the fractional portion to two decimal places, utilizing the round-to-even method. The example that follows indicates the variance between the three methods when compared to the sum of the unrounded numbers.

	BASIC DATA	ALWAYS-ROUND-UP METHOD	CONVENTIONAL METHOD	ROUND-TO-EVEN METHOD
	4.5	5	5	4
	3.2	4	3	3
	5.5	6	6	6
	4.8	5	5	5
	3.5	4	4	4
	8.5	9	9	8
SUM	30.0	33	32	30

(2) In many cases, the rounding will not be made to the whole number, but a different degree of accuracy. For example, if 9,228,938.5 were to be used as a general estimate, it would be more manageable and meaningful to round to thousands. In this case, we would ask if 938.5 is nearer to 1,000 or to 0. Of course, the answer is 1,000 and, therefore, 9,228,938.5 is nearer to 9,229,000 than to 9,228,000. This is rounding to a specific number of significant digits using the round-to-even method.

(3) In the round-to-even method, you should be aware of the cost of inventory. We are dealing in thousands of dollars worth of supplies and ordering several thousand at a time. In our earlier example, our basic data totaled 30. By always rounding up, we had 33 and the conventional method totaled 32, while if we used round-to-even method, our total was 30. Given a couple of years of demand data and steady demand, we may save thousands of dollars in inventory cost while still supplying the customer.

4. Averages.

a. By definition, an average is a measure of the location of the point of the central tendency. It is one figure that is representative of a mass of data. Although an average is representative of data as a whole, it reveals nothing about individual elements of the data.

b. The word “average” is used often, but there are actually several types of averages. They are the mean, median, and mode. We will deal with the arithmetic mean.

(1) The arithmetic mean (or simply mean) is the average which is used most frequently. The mean of a group of items may be obtained by adding all the items together and dividing the total by the number of items in the group. The characteristics of the mean are:

(a) The value is determined by every item.

(b) It is a calculated average.

(c) Computation is easy.

(d) Its value may be greatly distorted by extreme values.

Formula:

$$\bar{X} = \frac{\Sigma(X)}{N}$$

$\bar{X}$ = mean
Σ = sum of (Greek letter "sigma)
(X) = data expressed as individual items
N = number of items

(2) EXAMPLE: Find the mean Average Quarterly Demand (AQD):

1QX9 - 54	1QX0 - 73	1QX1 - 47
2QX9 - 33	2QX0 - 54	2QX1 - 50
3QX9 - 47	3QX0 - 47	
4QX9 - 61	4QX0 - 39	

Σ(X) = 505
N = 10
$X = \frac{505}{10} = 50.5$ (round to whole number using round-to-even method)

5. Moving Average.

a. This method is based on the prediction that demands in the future will be the same as the average demands in the past have been. That is, a mean average of demands experienced over a period of time up to the current period is calculated and used to forecast the future demand rate. The period of time over which demands are averaged is called the base period and is usually 1 to 2 years in length. The following example illustrates the use of the moving average.

(1) The demands for an item over the past fiscal year were tabulated as:

1QX0 - 26
2QX0 - 21
3QX0 - 17
4QX0 - 20

$$\bar{X} = \frac{\Sigma(X)}{N} = \frac{84}{4} = 21$$

Using a base period of 1 year, the average would be 21. Thus, the demands for this item in the future would be forecasted at a rate of 21 per quarter.

(2) After the actual demand for the next quarter (i.e., first quarter of the next fiscal year) is tabulated, a new average is calculated again using the <u>four most recent quarters</u>.

2QX0	-	21
3QX0	-	17
4QX0	-	20
1QX1	-	22
TOTAL		80

$$\Sigma\bar{X} = \frac{80}{4} = 20$$

Therefore, demands will be forecast now at a rate of 20 per quarter.

(3) Note that when a moving average is calculated, the newest period's demand is added and the oldest period's demand is deleted. <u>Thus, a moving average is simply a mean average which moves in time as new elements are added to the average and old elements are removed</u>.

(4) The following table shows a continuation of the same example over a 2-year period. This table demonstrates that in spite of the fact that the actual demand fluctuates up and down, the moving average stays relatively level. <u>Thus, the moving average acts to cancel the effects of random fluctuations</u>.

TIME PERIOD	ACTUAL DEMAND	FOUR-QUARTER TOTAL	FOUR-QUARTER MOVING AVERAGE
1QX0	26		
2QX0	21		
3QX0	17		
4QX0	20	84	21
1QX1	22	80	20
2QX1	27	86	22
3QX1	19	88	22
4QX1	21	89	22

b. The characteristics of smoothing out fluctuations in demand rates is desirable as long as there is no basic change in the pattern of demands. However, if there is a steadily increasing demand for an item, the moving average will prove to be a poor forecaster of future demands since it will lag behind this trend toward greater demands. If the trend is to decreased demands, the effect of using the demand rates experiences four or eight quarters ago (depending on the base period) will cause the moving average to react slowly to the trend of reduced demands.

(1) The following example will illustrate this fact and will also show the difference between using a four-quarter base period and an eight-quarter base period. The eight-quarter moving average always reacts slower to changes than the four-quarter moving average.

TIME PERIOD	ACTUAL DEMAND	FOUR-QTR TOTAL	FOUR-QTR MOVING AVG	EIGHT-QTR TOTAL	EIGHT-QTR MOVING AVG
1QX9	11				
2QX9	8				
3QX9	14				
4QX9	12	45	11		
1QX0	10	44	11		
2QX0	11	47	12		
3QX0	16	49	12		
4QX0	22	59	15	104	13
1QX1	26	75	19	119	15
2QX1	32	96	24	143	18
3QX1	35	115	29	164	20
4QX1	32	125	31	184	23
1QX2	33	132	33	207	26

(2) After quarter 1QX0, there is an obvious increasing trend in demand rates which continues through quarter 3QX1. The forecasts based on the four-quarter moving average are

quite accurate until this trend appears. However, after successive quarterly demands of 22 and 26, the four-quarter moving average at the end of the first quarter 1QX1 is still only 19. The eight-quarter moving average at the same time is only 15. After this upward trend levels off, the four-quarter moving average finally "catches up" to the new higher rate of demands after four more quarters. However, the eight-quarter moving average is still well below the current rate of demands and will remain below until 2 years (eight quarters) have passed at this new higher level.

(3) If there is no upward or downward trend in the demand rates, the eight-quarter moving average will generally produce a more accurate figure, since it is less susceptible to random fluctuations in demand. The objective in choosing a base period is to find one long enough to cancel the effects of random fluctuations in demand.

6. Weighted Moving Average.

a. Given a specific base period, it is still possible to modify the moving average by giving different amounts of emphasis to the different elements of demand data in the base period. Using the basic moving average method, each element of the demand data in the base period receives equal weight when determining the average. Each of the quarterly demand figures is weighted by ¼ or .25 with a four-quarter base. Using the demand data below, the four-quarter moving average may be calculated (using the previous method) to be 18. The equivalence of using weights of .25 for each quarter's demands is:

TIME PERIOD	ACTUAL DEMAND		MOVING AVERAGE WEIGHT		PRODUCT OF DEMAND AND WEIGHT
1QX1	13	x	.25	=	3.25
2QX1	17	x	.25	=	4.25
3QX1	19	x	.25	=	4.75
4QX1	23	x	.25	=	5.75
TOTALS	72		1.00		18.00 = Moving Average Forecast

b. Again, it is apparent that the moving average produces a figure which lags behind the apparent upward trend in demands. This is caused by the equal consideration or weight given to the outdated (early) low demands and the current increased demands. In order to avoid this difficulty, it is possible to increase the weight placed on recent data and decrease that placed on older data. The following table shows the effect of adopting a system which weights the most recent quarter's demands by .4 and the next recent quarter's demands by .3, .2, and .1, respectively. This method is called the weighted moving average.

TIME PERIOD	ACTUAL DEMAND		WEIGHT		PRODUCT OF DEMAND AND WEIGHT
1QX1	13	x	.1	=	1.3
2QX1	17	x	.2	=	3.4
3QX1	19	x	.3	=	5.7
4QX1	23	x	.4	=	9.2
TOTALS	72		1.00		19.6 or 20

As expected, this unequal weighted method produces a figure (20) more in line with the current demand rates than the equal moving average figure (18). However, the method involves quite extensive calculations, especially when an eight-quarter or larger base is used, and the assignment of weights is quite an arbitrary process. CCSS utilizes a weighted moving average in the forecast of demands for an item in the first 2 years during provisioning.

c. As long as conditions in the future are exactly as they have been in the past, moving averages can serve as a viable forecast of future demand. If we know of changes in the forecast period that will impact on the demands, we should modify our calculated moving average. The one technique we will examine is the PCF.

7. Program Change Factor (PCF).

a. Initial supplies of secondary items to support a new end item are distributed on a basis of the total number (density) of the end items that are in the field (in use). Engineering estimates formulated during the development stage are multiplied by the planned density to determine the quantities of parts to be supplied. Once the materiel is in the field and demand experience is accumulated, projects of future demand becomes susceptible to program changes. By "program changes" we mean changes in the density of end items in the field, changes in flying hours, changes in troop population, etc. Any increase or decrease in the program will cause changes in the future demand pattern for the supporting secondary items. We establish a factor which is used in conjunction with the historical demand rate to forecast demands. This factor is known as the PCF. The PCF acts to modify the average historical monthly demand figure to compensate for known program changes in the future. These factors are determined by dividing the forecasted average end item density during the forecast period by the historical average end item density during the base period. This computation gives you a number that is generally carried to two decimal places. The historical average demand rate is then multiplied by the PCF. This produces a forecasted average demand rate, which reflects the relative change of end item density. Perhaps at this point we should clarify what is meant by the "forecast period" and the "base period."

(1) Forecast Period. A planning horizon or a specific time in the future for which we are determining requirements. This period is determined by simply adding the number of months in the Acquisition Leadtime (AQLT) and the Economic Order Quantity Cycle (EOQCY) (AQLT of 9 months + EOQCY of 3 months equals a forecast period of 12 months).

(2) Base Period. The historical timeframe which relates to a specific number of months in the past. Generally, we are relating to

the demands generated during this historical period. It is extremely important for you to remember which base period was used when determining your forecast demand rate. This same period of time must be used when computing program change factors, percentage of return of unserviceable assets, etc.

b. Now, an example which will explain the development and the use of a PCF.

(1) Assume that you, as an item manager, are responsible for the management of a printed circuit board that is peculiar to one type of radio set. During the base period, in this case 12 months (end item density is usually computed in quarters), there was an average of 1,000 radio sets in use in the system. In that same 12-month period, the Average Monthly Demand (AMD) for the printed circuit board was 160 each. During the next 5 quarters or 15 months (forecast period), the projected average in-use density of the radio set will increase to 1,250 sets in the field. How many of your printed circuit boards will be required each month to support the radio sets in the future?

$$PCF = \frac{\text{Forecasted Average In-Use Density During the Forecast Period}}{\text{Historical Average In-Use Density During the Base Period}}$$

$$PCF = \frac{1{,}250}{1{,}000}$$

$$PCF = 1.25$$

Now, remember we said that the PCF was used to modify the historical average monthly demand to compensate for known changes in the future. Thus:

Historical AMD	=	160
PCF	=	x 1.25
Forecasted Average Monthly Demand	=	200

(2) As seen, we have adjusted our historical AMD (160) by the PCF (1.25) and computed a forecasted average monthly demand (200). If we were to examine what we have done, it appears quite logical that if an average of 160 printed circuit boards were needed to support 1,000 radio sets, more than 160 would be needed to support 1,250 radio sets. This is precisely what the PCF does for you; it modifies historical average demands to reflect program changes that will occur in the future.

(3) Use of the PCF results in providing computations which contemplate changes. Consideration must still be given to the accuracy of the density figure, age of the end item, and differing rates of deterioration and repair in varied areas and under diverse conditions.

8. Validate Demand Data.

a. Looking at a Supply Control Study (SCS), Demands and Returns section, we see the average monthly recurring demands are computed and printed. NOTE: For low-dollar value studies, this average is for all recurring and nonrecurring demands rolled up together.

In order to validate the demand data, we look at the Demands and Returns section of the SCS (see example below).

Demands and Returns	
Average Monthly Recurring Demands	189.66
Average Monthly Programmed Demands	
Balance Monthly Programmed Demands	
Gross Monthly Demands	189.66
Average Monthly Serviceable Returns	
Net Monthly Demands	189.66

b. We could also look at the National Stock Number Master Data Record (NSNMDR) (extract attached to the study), Sector 13, to see what the last base AMD was. NOTE: When we are looking at the NSNMDR extract, it is old data. If we ran another extract a day after our SCS, the AMD would (or should) match. What we are concerned with is if the demands and returns on the SCS are much higher or lower than the previous time the study was printed. If the numbers are fairly constant, no worry. If your last study shows that you made a buy and now you have a cutback, something is wrong!

c. Upon seeing a possible problem, we must continue to validate by turning to our Demand Depot Summary.

(1) Add up the total AMD demands at all locations.

(2) Subtract out programmed demands.

(3) Subtract out serviceable returns.

(4) Divide by base period (normally 24 months).

(5) Multiply by the PCF.

d. Prior to the computation of the base AMD, the total demands must be adjusted by serviceable returns and programmed demands. A Low Dollar Value (LDV) study will not include the following demands: Foreign Military Sales (recurring and nonrecurring), supply support arrangement, set assembly, initial issue, mobilization, and basic issue item demands. The Item Management Plan (IMP) will exclude all demands excluded by the LDV study as well as rebuild demands.

(1) Total Demands	730	2,264	1,353
% Total Demands	17%	52%	31%

Total Demands	=	4,347
Excluded Demands	=	- 98
Base Demands	=	4,249

(2) Serviceable returns are deducted from the base AMD up to the Maximum Serviceable Return (MAX-SVC-RTNS) rate accessed from Sector 13/01 of the NSNMDR or from the Materiel Management Decision (MMD) file. The DRD file contains the exact serviceable returns. The item manager can back calculate from the cover sheet of the study to determine the number of serviceable returns deducted.

Avg Mo Recurring Dmds ÷ PCF = Base AMD
Base AMD x 24 = Dmds Used
Dmds Used - Base Dmds = Serviceable Rtns

(3) The formula to calculate average monthly recurring demands is:

(Total Dmds - Programmed Dmds - Serviceable Rtns) ÷ 24 x PCF = Avg Mo Recurring Dmds

8. Summary.

a. We have stressed the need to develop a critical and questioning attitude toward numbers and the need to stay abreast of the ever-changing concepts and methods. We have learned some of the simpler techniques during this period to include rounding and averaging.

b. In rounding numbers, the “round-to-even” method has less bias than the “conventional” or the “always-round-up” method. The “round-to-even” method is more difficult to use, but the extra thinking and work required does overcome the consistent overstatements resulting from the other methods.

c. The moving average was discussed to show that it is a simple technique to compute and works well with those items that have fairly stable demand patterns. However, caution must be applied on those items that have unstable demand patterns or those items which require trend analysis. One major disadvantage of a straight moving average is that it is always lagging behind in time. This is particularly disadvantageous when a trend is present.

d. Weighted moving averages are more effective than straight moving averages. However, it must be recognized that the selection of the various weights is arbitrary.

e. The program change factor is the tool which makes Army forecasting work. An inaccurate PCF will create erroneous forecasts for all secondary items on a given weapon system. Both secondary item managers and major item managers must be concerned with ensuring PCF’s are valid.

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