CONTENTS

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1. INTRODUCTION

Inventory management is essentially concerned with supplying users with items in such a manner so as to minimize all the costs involved.

Generally, these costs can be grouped into 3 categories, namely, holding costs, ordering costs and costs associated with a stockout. A good inventory system can thus be said to be one which achieves good customer service at low cost.

Although the inventory manager generally will not have control over the abovementioned costs, it is nevertheless his duty to make his basic inventory management decisions, i.e. when to order stock and how much stock to order, in such a manner so as to ensure the total costs are minimized.

To aid him make these decisions the inventory manager will find that he requires a working system which he understands and trusts. The system used should, however, never supercede his human judgement and always be seen as an aid.

The aim of this document is to put forward an approach to one such system.

As stated previously, two decisions the inventory manager must make are:

- when to re-order stock and,
- how much to re-order.

These are two separate issues and will thus be dealt with separately.

2. HOW MUCH STOCK TO RE-ORDER

2.1 The amount of stock that is ordered is refered to as the order quantity (Q).

The optimum value of Q is obtained when the inventory holding cost is equal to the ordering cost. This is graphically depicted in FIG. 1. below.

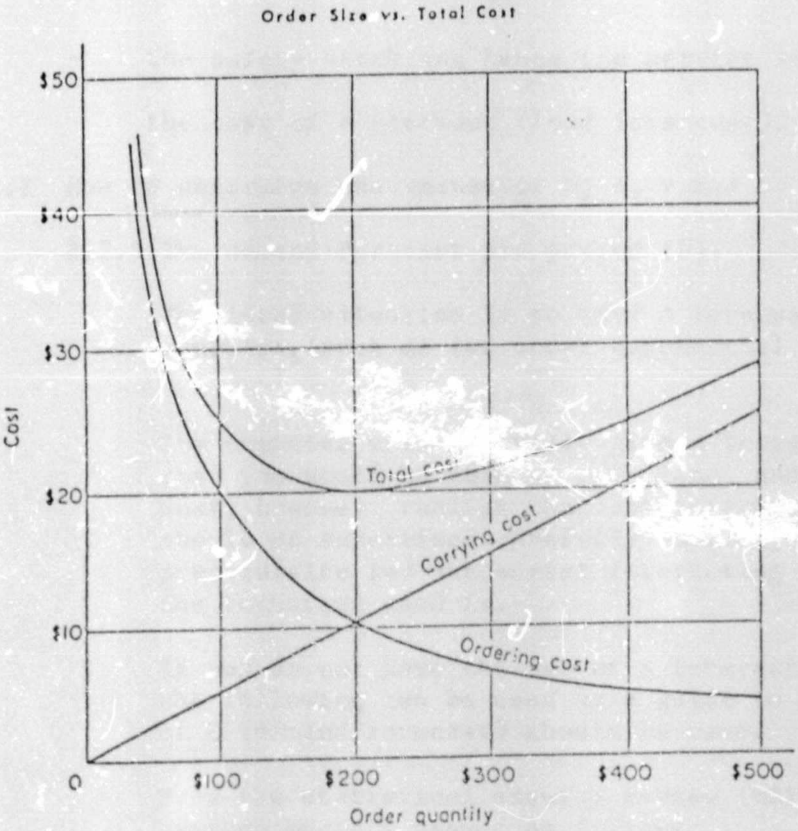


FIGURE 1

As can be seen from the graph, at this point the total cost (not including the stockout cost) is a minimum. It is interesting to note that the total cost curve is generally flatter to the right of the optimum than to the left. This implies that it is safer (from a cost point of view) to err slightly towards the high side of the EOQ than to the low side.

The minimum total cost (see figure 1) occurs when

$$Q = \sqrt{\frac{(2)(D)(A)}{(v)(r)}}$$

where Q = order quantity
D = the demand forecast per period
A = the purchase/ordering cost
v = the item price
r = the holding cost

Since the above value of Q is the optimum value obtained (by balancing the holding and ordering costs) it is usually denoted as Q* and refered to as the Economic Order Quantity (EOQ).

It is important to note that the EOQ does not depend on the following:

- the re-order point and hence the lead time.

- the safety stock and hence the service level.
- the cost of a stockout (load loss cost).

2.2 How to determine the values of D, A, v and r.

2.2.1 The demand forecast per period (D).

The ideal situation is to have a forecasting technique on computer, (such as 1st order exponential smoothing.)

The computer will generally give a better forecast value than you would be able to calculate, and far quicker. One must, however, realise that any forecasting technique used, should be supervised carefully. Human judgement is always a prerequisite for successful forecasting no matter how good the technique used is.

If you do not have the use of a forecasting technique, then the following can be used as a guide to determine what value of D (demand forecast) should be used.

From the statistical enquiry screen (MEY) determine the average monthly issues as follows:

(1 Months issues) /1 = average monthly issues
(3 Months issues) /3 = average monthly issues
(6 Months issues) /6 = average monthly issues
(12 Months issues) /12 = average monthly issues

Compare the 4 average monthly issues above and see if the 4 averages are (i) constant, (ii) irregular, (iii) increasing, or (iv) decreasing.

- For constant values use the average of the four averages for the value of D.
- For irregular values try and determine the cause for the increase or decrease and if the determined cause is not a factor this time then use the average of the values except the irregular one.
- For completely irregular values use the 12 months issues average.
- For increasing values use the 1 months issues value.
- For decreasing values use the 1 months issues value.
- Most importantly realise that common sence must be used and that the above is only a guide.

Another suggestion is to (if possible) obtain the monthly usages per item from the query master system and plot the usage on graph paper. This will enable you to (quickly) get a good idea of the item's usage pattern and hence facilitate a good forecast.

Note: - Take extreme care when determining the forecast demand, you could waste a lot of money if you are not carefull.

- Preallocations and stores transfers are included in the monthly issues. This may increase the demand of an item unrealistically and so the demand calculation should take this into account i e. exclude these sources of demand where applicable.

- If a stockout occurs, try to determine the cause. Do not over-react and immediately increase your order quantity, since the stockout has little to do with your order quantity.

- Stock has been stratified into A, B, C and D items (plus key and strategic). This is so that you can apply more control over those few vital items that constitute your major usage value, i e, concentrate your efforts on your A and B items.

- When an item arrives at the store, inform the relevant user by means of a memo that the item has arrived.

2.2.2 The ordering cost (A).

This is the average cost associated with placing one order, irrespective of the number of items on that order.

Each purchasing department should calculate their respective ordering costs since these costs could differ from department to department depending on the situation.

Calculation of the ordering costs should only take into account the marginal costs involved. (i e. do not include costs such as rent, depreciation of equipment etc.) The major costs will be the salaries of personnel.

The following costs have been calculated by the Commercial Department at Megawatt Park for their purchasing section, and can be used as a guide.

INTERNAL COST OF PLACING ORDER

° Stores purchasing of material if available from Bulk Contract: Issue Systems generated or handwritten T. DIN or Local Purchase Order: R45,00.

The above costs include the receipt of the material by stores.

° Stores purchasing if Enquiry must be issued, evaluation of tenders, issue of order and recipt of material. Orders to be placed for non stock items, following above procedure: R190,00.

° For material required to Escom Specification or S.A.B.S. etc., issue Enquiry, evaluation of Tenders, issue of order and receipt of Material: R430,00.

2.2.3 The item price (v).

This is simply the standard price of the item.

2.2.4 The inventory holding cost (r).

This cost can be calculated, but is usually determined by management. Corporate management at Escom have decided that the total inventory holding cost is to be taken as 30% per annum of the item price (for strategic reasons).

The holding cost includes such components as the following:

- Cost of invested capital.
- Deterioration and/or depreciation costs.
- Insurance costs.
- Obsolenscence costs.
- Storage costs.

These are more fully discussed below:

° Cost of Invested Capital.

Generally, the most critical of these costs is that of the capital tied up in inventory rather than invested elsewhere. It is taken as equal to the highest rate of return the company could obtain from alternative investments. For example, if a company expects to earn 18% on its total investment, and if money released from liquidation of inventories could also earn 18%, then 18% is the cost of the capital invested in inventory. Thus, the cost should be taken as the expected rate of return on capital projects for which capital is not currently available. Hence, the cost of capital must be set at the level dictated by management investment policy.

° Deterioration and/or depreciation costs.

Deterioration and/or depreciation costs incurred through ageing, by breakage, pilferage, etc. will normally be proportional to the total investment in inventory at any point in time and, therefore, can also be expressed as a percentage of the unit cost of an item.

° Obsolescence Costs.

Obsolescence costs are incurred when an item is no longer saleable due to changing conditions or customer perferences. The cost penalty for each item disposed of is the original cost plus the return on a good investment of that amount held from acquisition date to obsolescence date minus any salvage value. Obsolescence costs, always incurred at a fixed point in time, cannot be predicted with certainty in advance.

° Storage Costs.

Storage costs are incurred when the inventory needs a warehouse or storage facility with supervisory and operating personnel, material handling equipment, record keeping functions, etc. The costs of renting or of operating facilities may be essentially independent of the level of the inventory, or part of these costs may be independent, while the rest will fluctuate more or less proportionately with the inventory level.

2.3 A refinement to the EOQ formula.

A refinement of the EOQ formula is shown below. It is useful for when an item has a large amount of standard deviation in the demand that we want to take into account. The resultant Q* obtained, will not be drastically different, but may be worth taking into account.

$$Q^* = \frac{\sigma_D \times \sqrt{LT}}{b} + \sqrt{\frac{\sigma_D^2 \times LT}{b^2} + \frac{2 \times D \times A}{v \times r}}$$

where σ_D = standard deviation of lead time demand
LT = item lead time
b = 5,65 (constant)

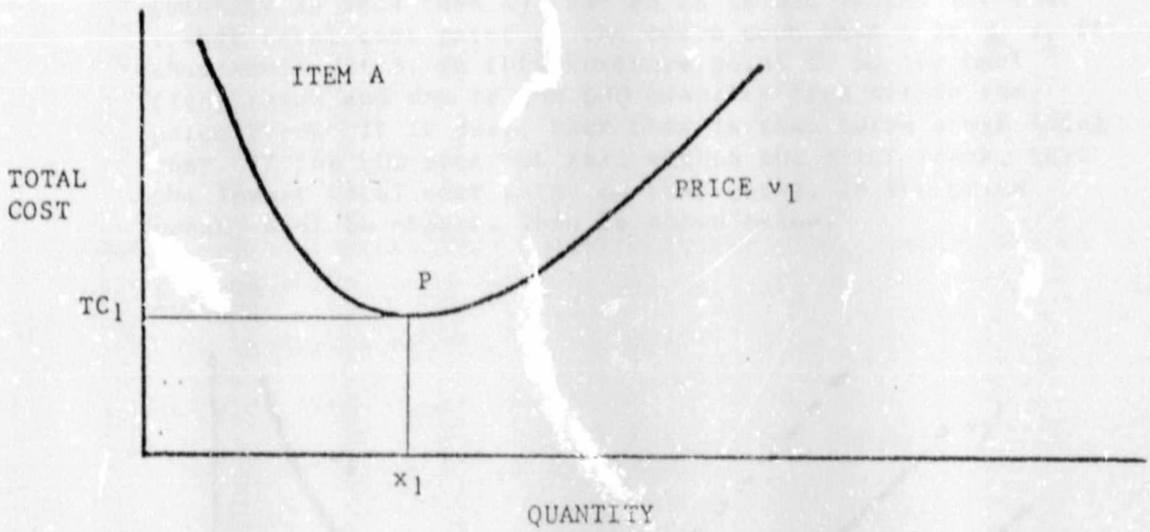
Note that as σ_D approaches zero the formula approaches the EOQ formula.

2.4 Calculating the EOQ for price breaks.

2.4.1 In some instances a lower price is offered for the same item if larger quantities are purchased. These non constant price situations are called price breaks.

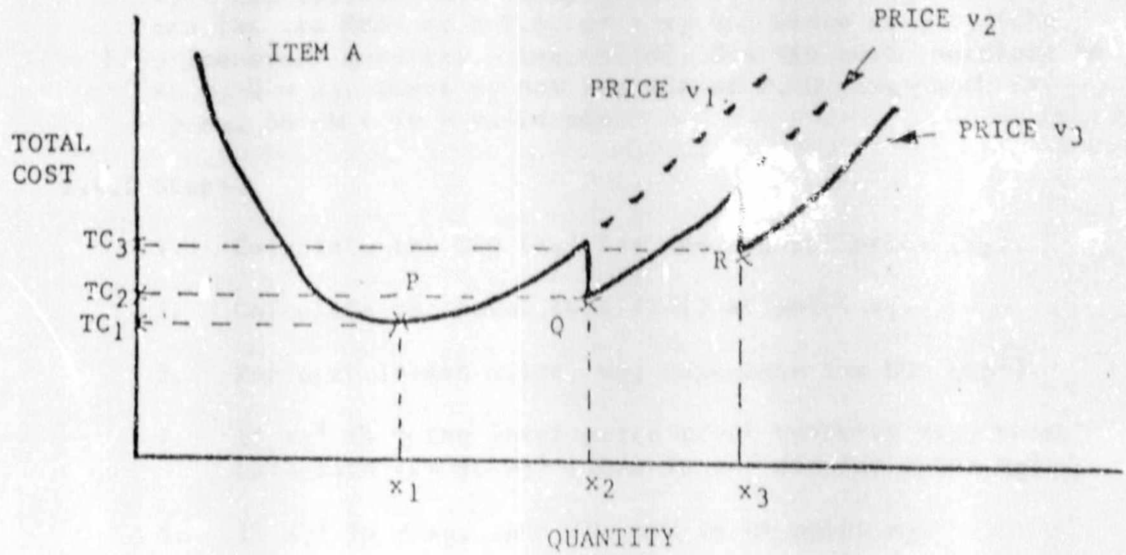
In section 2.1 the total cost curve was discussed. This will now be expanded upon and used to graphically explain the concept of price breaks.

Suppose item A which sells for a price of v_1 has the following total cost curve for all quantities sold i.e. no price breaks.



As can be seen the total cost is a minimum at point P, such that the total cost = TC_1 and the EOQ = x_1

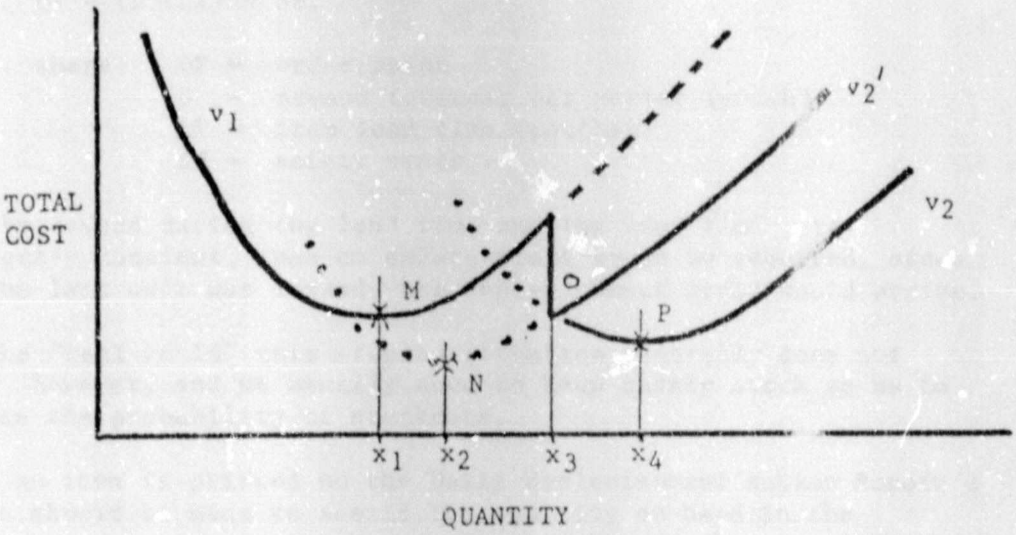
For that same item, now, suppose that the following price breaks exist. If a quantity of more than x_2 is purchased, then a price of v_2 is paid and for quantities of greater than x_3 a price of v_3 is paid. This situation is graphically depicted below.



The aim of the exercise is now to choose the total cost curve (TC_1, TC_2 or TC_3) which gives the lowest total cost. The curves are, however, only valid over the quantity range of the price break, i.e. curve v_2 can only be valid such that Q is greater than x_2.

It must also be noted that for curve v_1 the min cost occurs at the EOQ, i.e. point P. For curve v_2, the minimum cost also occurs at it's EOQ, but in this instance its EOQ quantity is less than x_2, and so it is not valid. The next lowest total cost point on the curve such that Q is $\geqslant x_2$ is thus chosen, i.e. in this instance point Q. So one must first check and see if the EOQ quantity lies within the price break. If it does, then this is that curve's min total cost. If the EOQ does not fall within the price break, then the lowest total cost point on that curve, in the price break, must be chosen. This is shown below.

Example:



Curve v_1 has min TC, at M i.e. order quantity $Q = x_1$. Curve v_2 - two options can exist, v_2, and $v_2{}^1$. Curve $v_2{}^1$ has its min (at its EOQ) at N i.e. $Q^* = x_2$ but since $x_2 < x_3$ (the price break quantity - not valid). Its min must therefore be at O, $Q = x_3$. Curve v_2 has its min at P, $Q = x_4$ which is $> x_3$, so this is a valid min.

2.4.2 Steps.

1. Calculate the EOQ (x_1) for the highest price (v_1).
2. Calculate the total cost (TC_1) at point x_1.
3. For next lowest price v_2, calculate the EOQ ($x_2{}^1$).
4. If $x_2{}^1$ is > price break quantity (x_2) then calculate this is the min for curve v_2).
5. If $x_2{}^1$ is $< x_2$, then TC_2 min is at point x_2.
6. Continue for further price breaks.
7. Compare TC_1 (min), TC_2 (min) and choose the lowest value.

8. The point at which the lowest TC value is found is the quantity Q(x) to be ordered.

3. WHEN TO RE-ORDER STOCK.

3.1 Stock is re-ordered/replenished when the order point is reached. In the Escom stock replenishment system, the computer will identify those items due for replenishment and print them on the Daily Replenishment Action Report.

The order point quantity must be calculated by the inventory manager and entered onto the computer system. The formula used to calculate the order point is:

$$OP = (D)(LT) + SS.$$

where OP = order point
D = demand forecast per period (month)
LT = item lead time (months)
SS = safety stock

If the demand during the lead time and the lead time were perfectly constant, then no safety stock would be required, since as the last unit was issued, the replenishment order would arrive.

In the "real world" this utopian situation generally does not hold, however, and we usually need to keep safety stock so as to reduce the probability of stockouts.

When an item is printed on the Daily Replenishment Action Report a check should be made to see if the quantity on hand in the computer correlates with the actual quantity in the store. With the high data inaccuracies in Escom stores, if this is done it will help eliminate incorrect data.

This is an especially useful time to do the stock count because the items being counted regularly will be the moving lines. The quantities to count are also low when the order point is reached. This is especially important for A and B items.

3.2 Discussion of terms in the OP formula:

3.2.1 Demand forecast per period (D).

This is the same value as used before in the EOQ formula.

3.2.2 Item lead time (LT).

It is vital that the item lead time (LT) used in the calculation is representative of the actual lead time. Although, (as far as possible) the LT should be constant for an item, since this is not always so, a realistic average of the last few lead times should be taken.

When evaluating prospective suppliers, one of the aspects which deserves attention is the supplier delivery lead time. Preference should be given to suppliers who can deliver in the shortest lead times, provided that their lead times are reasonably constant.

It is up to the buyers to pressurise the suppliers to meet specified lead times. If the delivery lead time is not going to be met, the buyer should immediately inform the inventory manager.

4 CALCULATING SAFETY STOCK (SS).

The amount of safety stock (also called buffer stock) held is dependant on the following factors:

- the desired service level (k)
- the standard deviation of demand during the lead time (σ_D)
- the length of the lead
- the standard deviation of the lead time (σ_L)
- the demand (D)

This results in the following equation:

$$ss = k \times (\sigma_D . \sqrt{LT} + \sigma_L D)$$

Usually the term $\sigma_L D$ resorts to zero since the lead time should be constant. If the lead time is not constant this will impact directly on the re-order point and result in excess safety stock being held. Another reason as to why the lead time should be constant is that the implementation of a MRP (Material Requirement Planning) system is, to a large extent, reliant on stable lead times and, since this is what we are aiming for, great effort should now be made in this direction. For a note on calculating the standard deviation (σ) see Appendix 2.

It is vital to note, once again, that the safety stock held bears no relation to the quantity of stock ordered (EOQ).

In fact, if both the demand during the lead time and the lead time were always constant, there would be no need for any safety stock.

4.1 Determining the desired service level (k).

Service level is a widely used measure of the effectiveness of a store. Essentially, if a store has a service level of 95%, then, statistically speaking, the store concerned should satisfy the demand placed on it 95% of the time, i.e. the probability of the store holding the item is 0,95.

Traditionally, a service level of between 95% and 99,9% is seen as desirable. It is vital to note that a service level of 100% is usually never aimed at, because of the high holding costs that would be associated with such a situation.

The service level can thus be seen as a way of balancing the customer requirements (usually wanting a service level of 100%) against the costs associated with achieving this.

The nature of Escom's stock requires the introduction of another term, the stockout cost (Cs). By the nature of its definition it is obvious that it is more important to hold critical items than non critical items. This implies that where critical items are concerned, a higher service level is justifiable, since the cost of not having that item (or the associated load loss cost) is offset by the higher holding costs.

An equation which satisfies the above scenario is shown below.

$$k = \frac{1}{b} \cdot \left[\frac{a - (4,605) \times (\sigma_D \times \sqrt{LT} \times (v).(r).Q^*)}{(b) \times (D) \times (Cs)} \right]$$

where k = standard normal deviate
σ_D = std deviation of demand
LT = lead time
C_S = cost per stockout
a = 5,65 for $1,3 < k < 3,2$
if $k < 1,3$, $a = 4,08$
b = 2,49 for $1,3 < k < 3,2$
if $k < 1,3$, $b = 1,32$

Difficulty is usually experienced when determining what the value of Cs is. For a note on calculating Cs see Appendix 3.

Once a value of k has been calculated, this can be translated into a service level percentage by using the standard normal distribution table attached, see Appendix 1.

For example, if the calculated value of k was such that k = 2,06 then from the table in Appendix 1 we get 0,98030 which represents a desired service level of 98%.

The abovementioned calculation of k is complex, and time consuming, but definitely worthwhile, especially for A and B items.

For C items it is recommended that little or no safety stock is held, and because of the relative unimportance of accurately determining safety stock levels for C items, a service level can be chosen, (usually 95%) and then this can be in turn translated to a value of k = 1,645 (via the normal distribution table).

If Cs cannot be determined for an item, then the abovementioned approach should be used, where the service level chosen, would depend on the relative importance of the item.

5. DETERMINING THE INVENTORY COSTS

We have essentially 3 costs, namely the holding or carrying cost, the ordering cost and the cost of a stockout. Probably the most realistic way to determine how effective various inventory systems are, is to compare the total costs of the options for a year.

5.1 The holding cost per annum (C_1)

This is made up of 2 parts, i.e. active stock and safety stock such that:

$$C_1 = \frac{Q^*}{2} x v x r + ss \times v \times r$$

5.2 The ordering cost per annum (C_2), such that:

$$C_2 = \frac{D \times 12}{Q^*} \times A$$

where A = ordering cost

5.3 Expected stockout penalty (C_3), such that:

$$C_3 = \frac{D \times 12}{Q} \times P \times Cs$$

where P = probability of a stockout

$$P = \frac{(100 - \text{service level } \%)}{100}$$

The total cost (T.C.) then, is the sum of the above, i.e.

$$\text{Total cost} = C_1 + C_2 + C_3$$

NOTE

For price breaks the equation for the TOTAL COST is:

$$TC = \left(\frac{Q}{2} \times v \times r\right) + \left(\frac{D \times 12}{Q} \times A\right) + (D \times 12 \times v)$$

So $\quad TC = C_1 + C_2 + D \times 12 \times v$

where D = monthly demand

6. APPENDICES:

- APPENDIX 1
- APPENDIX 2
- APPENDIX 3
- APPENDIX 4

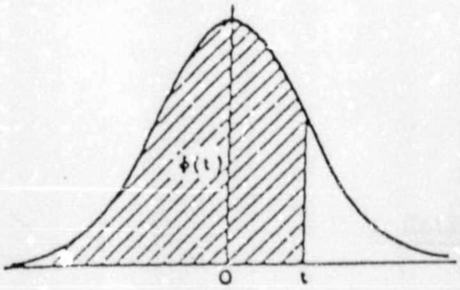


TABLE 1

The Cumulative Normal Distribution Function

$$\Phi(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{1}{2}t^2} dt$$

K	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
.4	.65554	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84850	.85083	.85313	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91308	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92786	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99915	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99967	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976

APPENDIX 2

CALCULATING THE STANDARD DEVIATION

The usual formula for calculating the standard deviation (σ) is given below where:

$$\sigma = \left[\frac{n \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2}{n(n-1)}\right]^{\frac{1}{2}}$$

An approximation to this formula which can be used is :

$$\sigma = \frac{\text{Max value - Min value}}{3}$$

This is especially useful if you have very limited or no raw data, e.g. you may think that you will normally use between 6 and 10 pumps of a certain type and, since you have no historical data of usage with which to calculate your standard deviation, you can apply the above formula as below:

$$\sigma = \frac{\text{Max value - Min value}}{3}$$

$$\sigma = \frac{10-6}{3}$$

$$\sigma = 1{,}33$$

APPENDIX 3

DETERMINATION OF STOCKOUT COSTS (C_S)

These are all the costs associated with not having the item in stock and may include the following:

- cost of expediting/rushed order
- cost of having limited capacity
- safety, etc.

The cost of equipment being down is difficult to calculate but an attempt must be made. Various factors should be taken into account such as the capacity requirements, i.e. if there is spare capacity then the [illegible] will be reduced.

You will have to rely on your Engineering and Maintenance sta[illegible]rmine these costs. You may find that there is very little justificati[illegible] holding many items.

One method of calculating C_S is shown below.

C_S = (MW hrs lost per incident) X (Cost per MW hr lost) X (down time)

where:- MW hrs lost per incident can be obtained from EPARMS

- cost per MW hr lost is read off table attached. (see pg 18-20)
- Down time = item lead time.

Example

The following information was obtained from the EPARMS system. The item under consideration was a mill table bottom ring. It had the following particulars:

Actual MW HRS lost due to bottom ring replacements	4372 MW HRS.
Number of incidents	7
Average MW loss caused per outage	126 MW
Min and max MW loss recorded	60-100 MW
Lead time (min)	6 months
Price	R64 000

Answer

$$C_S = (126)\ (1499350 \times \frac{126}{100} \times \frac{6}{12})$$

$C_S = R1,1901 \times 10^8$ per outage if no stock was on hand and it took 6 months to arrive. (Assumed group A power station.)

The cost per MW hr lost was calculated by Generation Performance in March 1986 using the PRDCST PROGRAMME. (See Tables 2 - 4)

The power stations have been grouped as shown below.

STATION GROUPS

GROUP A	KRIEL, ARNOT, HENDRINA, DUVHA
GROUP B	KOMATI, CAMDEN, MATLA
GROUP C	INGAGANE, GROOTVLEI, WILGE
GROUP D	TAAIBOS, HIGHVELD, VAAL, VIERFONTEIN
GROUP E	WESTBANK, SALTRIVER, HEXRIVER, UMGENI

Each group has different costs.

NOTE:

- The costs per MW hr lost shown in tables 2 - 4 are the costs for the MW loss indicated for the year shown (entire year). In other words it will cost Escom R1 499 350 if 100 MW is lost for the entire year of 1986 for a group A power station.

- The cost increase related to increased MW loss is not linear. This means that for a group A station, for example, 6 units all losing 100 MW does not equal 1 unit losing 600 MW, i.e. 6 x 1 499 350 = 10 652 253. For our purposes, the cost increases between the MW increase increments, can be assumed to be linear. In other words, a MW loss of 250 MW for the year for a group A station would cost $\frac{250}{200}$ x 3 062 295 = R3 827 869.

COST INCREASE OF GROUP A

DERATING

YEAR	100 MW	200 MW	400 MW	600 MW
1986	1499350	3062295	6462306	10165253
1987	971973	1966953	4057481	6224758
1988	904909	1823748	3753508	5761440
1989	898338	1803619	3671879	5576987
1990	916121	1841333	3778543	5801683
1991	861382	1731329	3545121	5417364
1992	887595	1786454	3651531	5583322
1993	1019448	2056762	4232946	6463461
1994	1184779	2382009	4868675	7404941
1995	1355287	2736764	5635626	8690223

COST INCREASE OF GROUP B

DERATING

YEAR	100 MW	200 MW	400 MW	600 MW
1986	629973	1321300	2903907	4759178
1987	183773	390251	873594	1442935
1988	120420	252469	577744	983636
1989	107762	222324	471824	757432
1990	119964	248457	548956	925727
1991	96879	202229	450662	751869
1992	111494	204495	511117	847221
1993	218620	456804	996471	1594045
1994	361229	739098	1542080	2402251
1995	510387	1053507	2228101	3566806

TABLE 2

COST INCREASE OF GROUP C

DERATING

YEAR	50 MW	100 MW	200 MW	400 MW	600 MW
1986	122564	236516	525985	1290870	2332143
1987	2184	4469	9654	23339	42016
1988	750	1492	3106	21838	39723
1989	1146	2390	5234	15575	27798
1990	2620	5351	11457	31467	58108
1991	1509	3080	6617	19514	33651
1992	2019	4004	8535	23759	40241
1993	8022	16317	34532	92926	155633
1994	22192	45124	95254	229097	385625
1995	69222	142796	307725	740221	1313881

TABLE 3

COST INCREASE OF GROUP D

DERATING

YEAR	25 MW	50 MW	100 MW	200 MW	400 MW	500 MW	600 MW
1986	12394	25527	59251	146586	413695	597925	921140
1987	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	73
1993	0	0	0	5	29	51	1186
1994	14	28	59	127	372	765	533474
1995	7693	156370	34572	86395	250510	381508	

COST INCREASE OF GROUP E

DERATING

YEAR	25 MW	50 MW	100 MW	200 MW	400 MW	500 MW	600 MW
1986	59	100	268	626	-2222	-14160	-40213
1987	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0
1995	73	146	335	700	-11356	-23969	-46548

TABLE 4

APPENDIX 4

EXAMPLE 1

EXAMPLE 2

EXAMPLE 3

EXAMPLE 4

EXAMPLE 5

EXAMPLE 6

EXAMPLE 1

An item has the following particulars:

Floor polish - monthly usage 996 tins (c item)
- price R2,70 per tin
- polish bought on LPO.

What quantity should be ordered?

Present system

According to PA 041 the order quantity (OQ) should be between 6 and 12 months' supply for c items.

So, OQ = 996 x 6 to = 996 x 12
= 5 976 tins = 11 952 tins

So, order (say) 10 000 tins.

Proposed system

Since the item is bought on LPO, the ordering cost (A) = R45.
The inventory holding cost is taken as 30%.

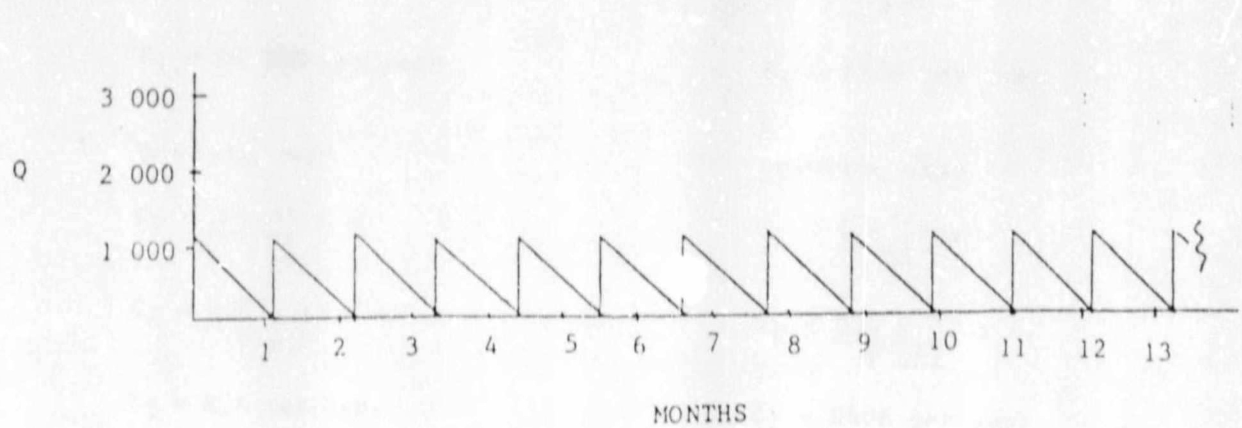
$$Q^* = \sqrt{\frac{2.D.A.}{v.r}} \quad \sqrt{\frac{2 \times (996 \times 12) \times 45}{2,7 \times 0,3}} = 1152 \text{ tins}$$

So order 1152 tins when the order point is hit.

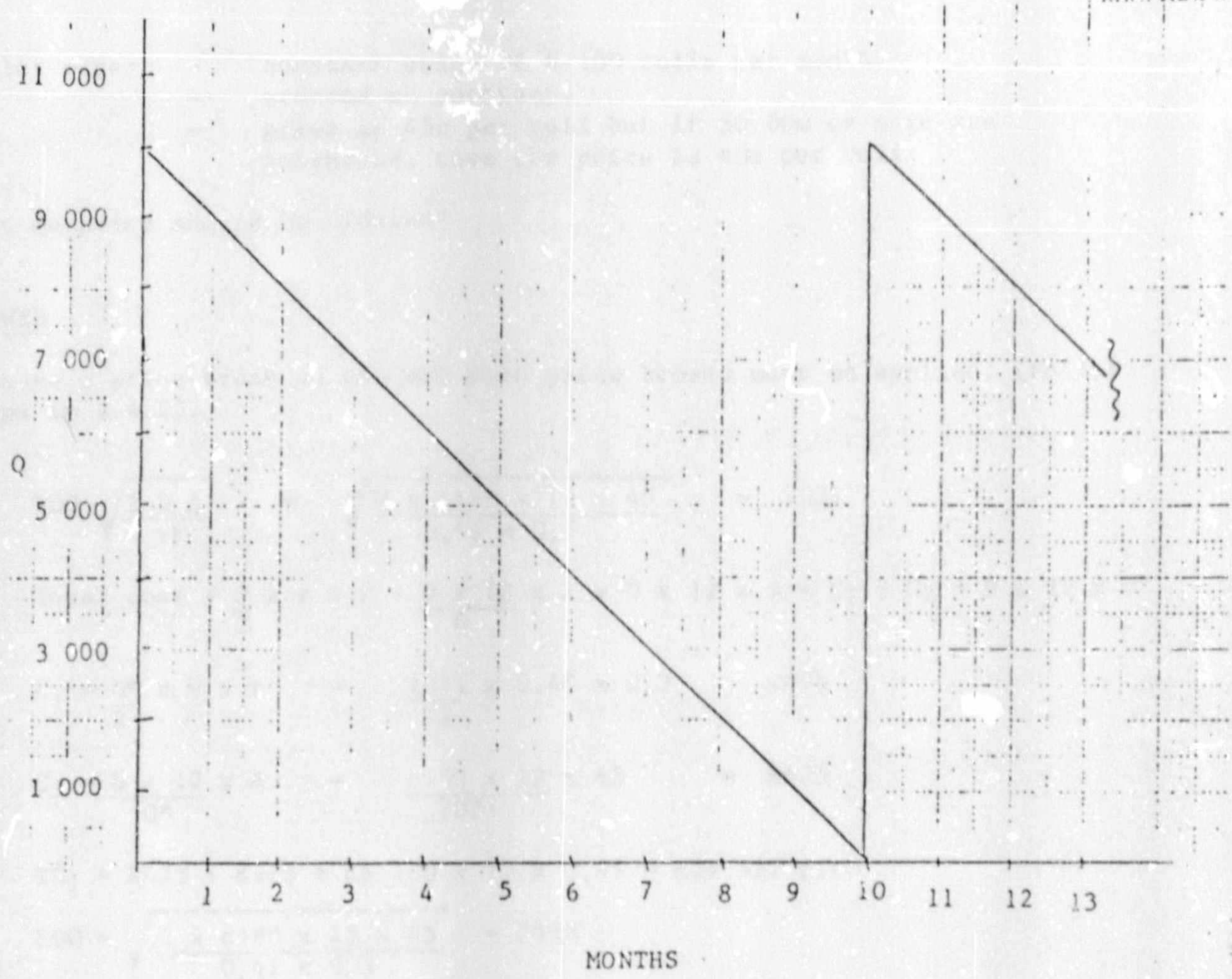
Comparison of the approaches

Present system - place 1,2 orders per year (i.e. every 10 months)
Proposed system - place $\frac{996 \times 12}{1152}$ = 10,4 orders per year.

Proposed



Present



PRESENT SYSTEM COSTS

- Holding cost

$C_1 = \frac{Q}{2} \times v \times r$

$C_1 = \frac{10\ 000}{2} \times 2,7 \times 0,3$

$C_1 =$ R4 050 per year

- Ordering cost

$C_2 = \frac{D \times 12}{Q} \times A$

$C_2 = \frac{996 \times 12}{10\ 000} \times 45$

$C_2 =$ R54 per year

- Total $(C_1 + C_2) =$ R4 104 p.a.

PROPOSED SYSTEM COSTS

- Holding cost

$C_1 = \frac{Q^*}{2} \times v \times r$

$C_1 = \frac{1\ 152}{2} \times 2,7 \times 0,3$

$C_1 =$ R466 per year

- Ordering cost

$C_2 = \frac{D \times 12}{Q^*} \times A$

$C_2 = \frac{996 \times 12}{1\ 152} \times 45$

$C_2 =$ R466 per year

- Total $(C_1 + C_2) =$ R932 p.a.

So it is 4,4 times cheaper to place 10,4 orders per year of 1 152 tins each.

Example 2

Toilet paper - constant usage of 6 180 rolls per month.
- ordered on contract.
- price is 45c per roll but if 50 000 or more are purchased, then the price is 40c per roll.

What quantity should be ordered?

ANSWER

We have a price break so the EOQ with price breaks must be applied. (Follow steps in 2.4.2).

1. $EOQ = \sqrt{\frac{2\ D\ A}{vr}} = \sqrt{\frac{2 \times 6180 \times 12 \times 45}{0,45 \times 0,3}} = 7031$

2. $\text{Total cost} = \frac{Q}{2} \times v \times r + \frac{D \times 12}{Q} \times A + D \times 12 \times v = C_1 + C_2 + D \times 12 \times v$

$C_1 = \frac{Q^*}{2} \times v \times r = \frac{7031}{2} \times 0,45 \times 0,3 = R475$

$C_2 = \frac{D \times 12}{Q^*} \times A = \frac{6180 \times 12}{7031} \times 45 = R475$

$TC_1 = R475 + R475 + R6\ 180 \times 12 \times 0,45 = R34\ 322$ p.a.

3. $EOQ = \sqrt{\frac{2 \times 6180 \times 12 \times 45}{0,41 \times 0,3}} = 7458$

4. Since EOQ quantity for $v = 0,41$ is $<$ the price break qty, the min cost for curve $v = 0,41$ is at the price break qty of 50 000.

$TC_2 = \frac{Q}{2} \times v \times r + \frac{D \times 12}{Q} \times A + D \times 12 \times v = C_1 + C_2 + D \times 12 \times v$

$C_1 = \frac{50\ 000}{2} \times 0,41 \times 0,3 = R3\ 075$

$C_2 = \frac{6180 \times 12 \times 45}{50\ 000} = R67$

$TC_2 = R3\ 075 + R67 + 6180 \times 12 \times 0,41 = R33\ 547$ p.a.

5. Compare TC_1 and TC_2.

$TC_1 = R34\ 332$
$TC_2 = R33\ 547$

6. Order $Q = 50\ 000$ rolls at the price $v = 0,41$, since $TC_2 < TC_1$

Compare to present system (PA 041)

B item, so order 4 to 8 months supply

$$OQ = 4 \times 6180 = 24\ 720 \text{ at } 45c$$

or $$OQ = 8 \times 6180 = 49\ 440 \text{ at } 45c$$

Since you pay 41c for 50 000 - lets order 50 000.
This would have given the costs above i.e. TC_2 = R33 547.

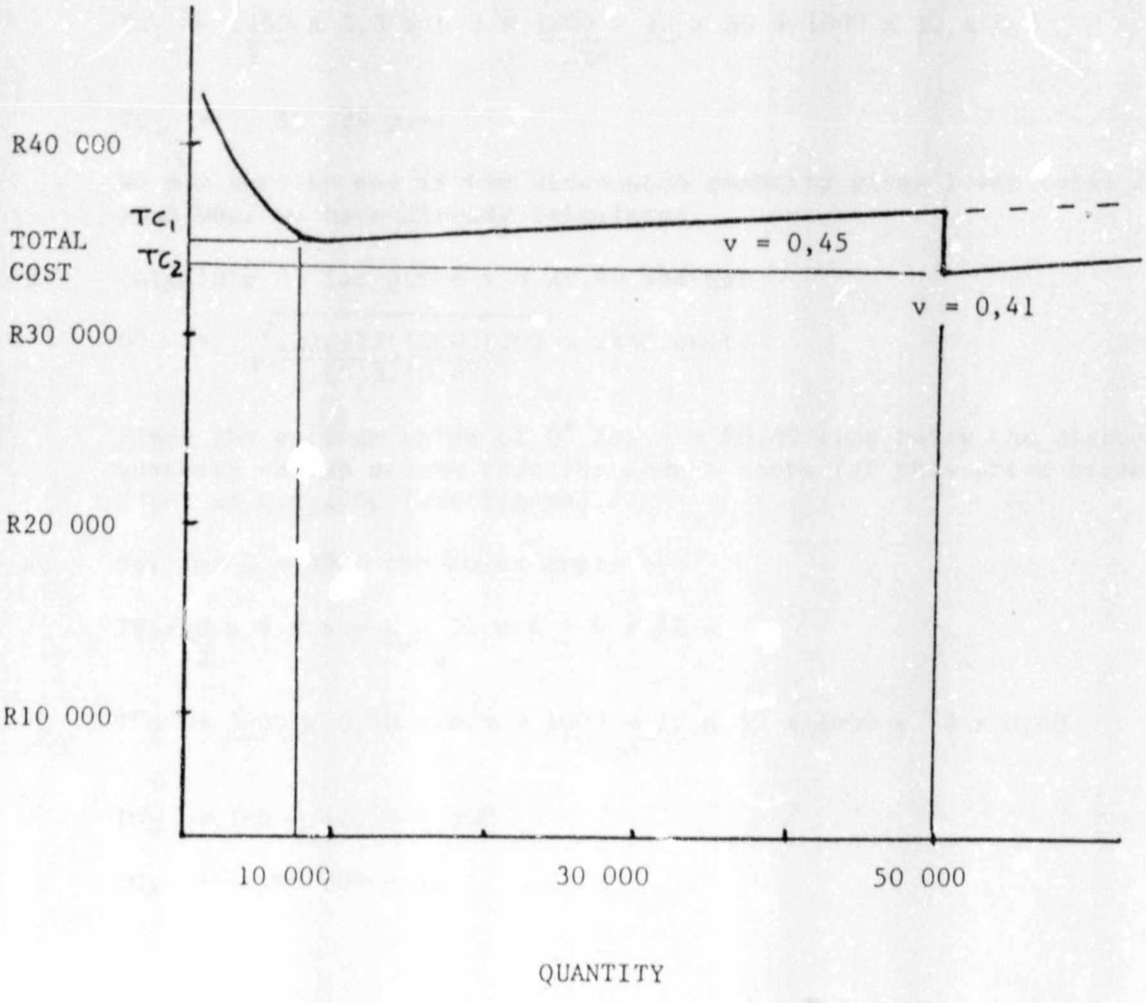
If only 25 000 had been ordered at 45c

$$TC = \frac{Q}{2} \times v \times r + \frac{D \times 12}{Q} \times A + D \times 12 \times v$$

$$TC = \frac{25\ 000}{2} \times 0,45 \times 0,3 + \frac{6180 \times 12}{25\ 000} \times 45 + 6180 \times 12 \times 0,45$$

$$TC = R1\ 688 + R133 + R33\ 372$$
$$TC = R35\ 193.$$

TOTAL COST VS ORDER QUANTITY



EXAMPLE 3

An item has the following applicable data.

D	=	1000 per month
A	=	R30 per order
r	=	30% per annum
LT	=	1 month

If you purchase a quantity of less than 3000 then v = R0,50 per item and if you purchase 3000 or more then the item price is R0,40 each.

Assume (in this instance) that $\sigma_D = 0$
i.e. that the demand is exactly 1000 per month and that the lead time is also always constant.

STEPS:

1. Calculate Q^* for price v = R0,50 and get

$$Q^* = \sqrt{\frac{2DA}{vr}} = \sqrt{\frac{(2)(12)(1000)(30)}{(0,3)(0,5)}} = 2190 \text{ units}$$

2. Now calculate the costs using,

$$TC = \frac{Q}{2} \times v \times r + \frac{D \times 12}{Q} \times A + D \times 12 \times v$$

$$TC_1 = \frac{2190}{2} \times 0,5 \times 0,3 + \frac{1000 \times 12}{2190} \times 30 + 1000 \times 12 \times 0,5$$

$$TC_1 = \text{R6 328 p.a.}$$

We now want to see if the discounted quantity gives lower total costs than what we have already calculated.

3. Calculate Q^* for price v = R0,40 and get

$$Q^* = \sqrt{\frac{(2)(12)(1000)(30)}{(0,3)(0,4)}} = 2450 \text{ units}$$

Since the optimum value of Q^* for v = R0,40 lies below the discount quantity we can assume that the lowest costs for this price break will occur at Q = 3000 (see figure).

4. So, for Q = 3000 the costs are:

$$TC = \frac{Q}{2} \times v \times r + \frac{D \times 12}{Q} \times A + D \times 12 \times v$$

$$TC_2 = \frac{3000}{2} \times 0,40 \times 0,3 + \frac{1000 \times 12}{3000} \times 30 + 1000 \times 12 \times 0,40$$

$$TC_2 = 180 + 120 + 4\ 800$$

$$TC_2 = \text{R5 100 p.a.}$$