FIT3158 Note - W8 Inventory Modelling under uncertainty

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1. Review of the Normal Distribution

2. Single-Period Order Quantity Model

What is that?

- A single-period order quantity model (sometimes called the newsboy/newsvendor problem) deals with a situation when ONLY ONE order is placed for the item and the demand is probabilistic.
- If the period's demand exceeds the order quantity, the demand is not back-ordered and revenue (profit) will be lost.
- If demand is less than the order quantity, the surplus stock is sold at the end of the period (usually for less than the original purchase price).

▼ What are the parameters needed to calculate that?

Unit cost = c
Penalty for item held at end of inventory cycle = h_E
Penalty for each item short (goodwill, etc.) = P_S
Selling Price = P_R

▼ Why is this called the newsboy problem? (Here)

- A newsboy who stands on the corner and sells papers to passers-by must order the papers the day before. He only has one chance to order because the papers only have any value on the day they are published; the next day they are worth nothing.
- If he orders too many he'll have to absorb the loss of the unsold papers, and if he orders too few he will have lost profits and annoyed customers. Getting the order quantity correct is how the newsboy makes the most profit.

▼ What are the assumptions?

w6l1_ShortageCosts_ANNOTATED_v20.pdf (edx.org)

- Period demand follows a known probability distribution. For example:
  - normal: mean is μ, standard deviation is σ
  - uniform: minimum is *a*, maximum is *b*
- Cost of over-estimating demand: $\$c_v$
- Cost of under-estimating demand: $\$c_u$
- Shortages are not back-ordered.
- Period-end stock is sold for salvage or discarded and is not sold in the following period.

▼ How do I know if h_e is +ve or -ve?

If you get some money back, h_e is -ve. This is because it reduces the cost of overestimating.

- Christmas Example: If the cost of a Christmas tree = \$10, but because the item could not be sold after Christmas, you sell it for clearance at the price of \$6 at the end of inventory cycle. So, $h_e = -6$,and cost of overestimating = $C_o = 10 - 6 = 4$ which means you lose \$4.

If you dun get some money back, like you are paying more money to dispose the unsold items, then it is a +ve.

- Newspaper Example: If the cost of a newspaper = 1, but because the item could not be sold after today, you cost $0.3 to burn and diose them. So, since you cannot get the money back but costing you as a penalty, $h_e = 3$

3. Re-order Point Quantity Model

What is that?

- A firm's inventory position consists of the on-hand inventory plus on-order inventory (all amounts previously ordered but not yet received).
- An inventory item is re-ordered when the item's inventory position reaches a predetermined value, referred to as the reorder point.
- The **re-order point** represents the quantity available to meet demand during lead time.
- **Lead time** is the time span starting when the replenishment order is placed and ending when the order arrives
  - Under deterministic conditions, when both demand and lead time are constant, the re-order point associated with EOQ-based models is set equal to lead time demand.
  - Under probabilistic conditions, when demand and/or lead time varies, the re-order point often includes safety stock

▼ What are the assumptions?

- Lead-time demand is normally distributed with mean μ and standard deviation σ.
- Approximate optimal order quantity: EOQ
- Service level is defined in terms of the probability of no stockouts during lead time and is reflected in z.
- Shortages are not back-ordered.
- Inventory position is reviewed continuously.

Why do we need this model?

$$\text{Reorder Point}: r = \mu + z\sigma$$

When-to-Order. This formula tells you the point where you need to re-order your stocks to avoid shortage.

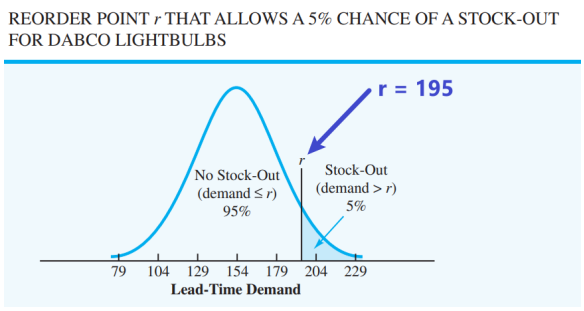
What is the relationship between re-order point and re-order quantity? (Here)

Reorder quantity and reorder points work in tandem to achieve optimal inventory management. Once you receive a reorder point alert, you can calculate the reorder quantity to determine the exact inventory replenishment needed in your fulfilment centre.

What is Safety Stock and Service Level?

- Safety stock is the amount by which the re-order point exceeds the expected (average) lead time demand. Example can be seen (Here)
    - In another word, the amount of safety stock in a re-order point determines the chance of a stockout during lead time.
- The complement of this chance is called the service level.
- Service level, in this context, is defined as the probability of not incurring a stockout during any one lead time.
- Service level, in this context, also is the long-run proportion of lead times in which no stockouts occur.

Interpretation of this model



Now, given that the mean $\mu = 154$, after calculations, we know $r = 195$; $Q* = 400$

What does r and $Q*$ tell us?

- The recommended inventory decision is to order 400 units whenever the inventory reaches the reorder point of 195.

How do you get Safety Stock?

To get safety stock, we need r and mean (μ), then get the diff:

- Because the mean or expected demand during the lead time is 154 units, the $195 - 154 = 41$ units serve as a safety stock,
- Safety stock absorbs higher-than-usual demand during the lead time.
- Roughly 95% of the time, the 195 units will be able to satisfy demand during the lead time. T

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4. Periodic-review Order Quantity Model

What is that?

- Before understanding this, you need to know its opposition — ***Continuous review inventory system —*** which means the system monitored continuously so that an order can be placed whenever the reorder point is reached.
    - Single-Period Order Quantity Model, and Re-order Point Quantity Model are computerised based on the ***Continuous review inventory system.***
- So, the alternative is periodic review system — its inventory level is checked and re-ordering is done **only at specified points in time** (at fixed intervals usually, such as weekly, biweekly, monthly).
- Assuming the demand rate varies, the order quantity will vary from one review period to another. (This is in contrast to the continuous review system in which inventory is monitored continuously and a fixed-quantity order can be placed whenever the re-order point is reached.)
- At the time a periodic-review order quantity is being decided, the concern is that the on-hand inventory and the quantity being ordered is enough to satisfy demand from the time this order is placed until the next order isreceived (not placed).

▼ **What are the assumptions?**

- Inventory position is reviewed at constant intervals (periods).
- Demand during review period plus lead time period is Normally distributed with mean μ and standard deviation σ.
- Service level is defined in terms of the probability of no stockouts during a review period plus lead time period and is reflected in z.
- On-hand inventory at ordering time: I
- Shortages are not back-ordered.
- Lead time is less than the length of the review period.

Formulae

Inventory Models: Stochastic Demand

Inventory models under random demand, assumed to be normally distributed with mean μ and standard deviation σ.

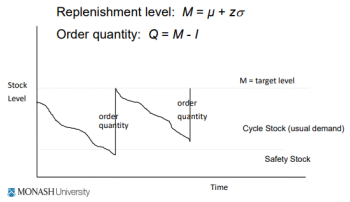
Single Period Order Quantity	Reorder Point Model
$P(demand < Q^*) = \frac{C_u}{C_u + C_v}$, $Q^* = \mu + z\sigma$ Cost of overestimating demand: $C_v = h_E + c$ Cost of underestimating demand: $C_u = P_S + P_R - c$ Where: Unit cost = c Penalty for item held at end of inventory cycle = h_E Penalty for each item short (goodwill, etc.) = P_S Selling Price = P_R	Reorder Point : $r = \mu + z\sigma$ Average Inventory : $\frac{Q}{2} + z\sigma$ Total Annual Cost : $\left(\frac{Q}{2} + z\sigma\right)ch + \frac{Ak}{Q}$

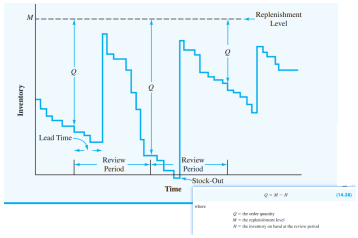
Periodic Review Order Quantity

- Formulas

Replenishment level: $M = \mu + z\sigma$

Order quantity: $Q = M - I$





▼ Cumulative Probabilities for the Standard Normal Distribution

Cumulative Probabilities for the Standard Normal Distribution

Table gives P(Z<z) for Z = N(0,1)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
3.6	0.9998	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.7	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.8	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
3.9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000