Resources

Z-Score to P-Value: <https://planetcalc.com/7775/>

P-Value to Z-Score: <https://planetcalc.com/7803/>

Week 1: Product Process Analysis & Little’s Law

## **Inventory Build-Up Diagram:**

**Flow time** is the time it takes a unit to go through a process.

**Cycle time** is the time between units leaving the process (interval between units).

**Capacity** is the maximum output rate when working at full speed, capacity is a rate!

**Utilisation** is how much the process/resources is used relative to its capacity.

**Bottleneck** is the process with the highest utilisation.

## **Little’s Law:**

Week 2: Product Process Matrix & Inventory Build-Up

Inventory Build-Up Diagram:

If demand < capacity, then...

and .

If demand > capacity, then...

and .

and .

**Product Process Matrix:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | One of a Kind | Low Volume, Custom | Medium Volume, High Variety | High Volume, Low Variety (Standardised) | Very High Volume, Almost No Variety (Commodity Products) |
| JOB SHOP | Project | Spaceship |  |  | High Variable Costs | Lost Sales |
| Job Shop |  | Luxury and Sports Cars |  |  |  |
| Batch |  |  | Jeans |  |  |
| FLOW SHOP | Assembly Line |  |  |  | Basic Passenger Vehicles |  |
| Continuous Flow | High Capital Costs | Low Utilisation |  |  | Raw Materials, Commodities |

# Week 3: Waiting Times

## **Denotations & Formulae always applicable:**

a = arrival time

p = processing time

Ra = Arrival rate = 1/a and a = 1/Ra

Rp = Processing rate = 1/p and p = 1/Rp

u = Utilisation

Tq = Waiting time

Iq = Average number of units waiting

Ip = Average number being processed

Isys = Average number in the system

Tsys = Average time in the system

## **CVa, CVp & Poisson Distribution:**

CV = Coefficient of Variation

If there is no variation at all, meaning either a or p are fully **constant,** then there is no variation. Ergo, .

If the arrival time is exponentially distributed, we are looking at a Poisson arrival process. Ergo, .

If the processing time is exponentially distributed, . Note, that in the case of processing time we are not talking about Poisson distributions.

### **VUT Equation & More Formulae for m = 1:**

***Assumptions for VUT Formula:***

* VUT provides long-term, steady state waiting time
* u < 1, meaning no inventory build-up
* VUT assumes infinite buffer size
* VUT equations are a good approximation but highly exact, when m=1 and arrivals follow Poisson

*u* **= =**

Waiting Time Cost per Day =

### **VUT Equation & More Formulae for m > 1:**

|  |
| --- |
| **SEPERATE LINES MULTIPLE SERVERS:** When units arrive at each server separately, meaning separate lines, then you use the single server formulae. Essentially each unit is then considered to be served by only one server. |

|  |
| --- |
| **JOINT LINES MULTIPLE SERVERS:** When units queue together, then the arrival time is divided by m and you continue to use the single server formulae. |

|  |  |  |
| --- | --- | --- |
|  | **JOINT QUEUE** | **SEPERATE QUEUE** |
| a |  |  |
| u |  |  |
| Tq |  |  |

# Week 4: Inventory Management: Newsvendor Model Pt. 1

## **Definitions & Denotations:**

SL = Service level is the defined as in-stock probability.

Q\* = Optimal quantity

= Cost of understocking one quantity, “Underage”

= Cost of overstocking one quantity, “Overage”

D = Demand

= Mean demand

= Standard deviation of demand

= z-score for the service level, find it in the z-score table for 1-SL

L = Lead time

T = Review period (when you reorder)

## **Formulae for PERIODIC REVIEW, NORMAL DISTRIBUTION:**

Cost – Benefit Calculation / Marginal Analysis

vs.

Service Level and Optimal Quantity

Q\* =

Deterministic Demand, meaning demand is certain and constant

Target Stock Level = Demand during T+L

**Formulae for Calculating the Probability from Demand and Frequency DETERMINISTIC:**

Given the table...

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Demand | 1 | 2 | 3 | 4 |
| Frequency | 5 | 3 | 4 | 2 |
| Probability | =5/(5+3+4+2) |  |  |  |
| Cumulative Probability |  |  |  |  |

, meaning the frequency of X divided by the sum of all frequencies

, meaning the sum of all probabilities up to X

# Week 5 Part 1: Inventory Management: Newsvendor Model Pt. 2 **Definitions & Denotations:**

Excess Inventory/Overstocking = Target Stock Level > Demand during T+L

Excess Demand/Understocking = Target Stock Level < Demand during T+L

EP = Exposure period, with

SS = Safety Stock

## **Formulae for PERIODIC REVIEW WITH EXPOSURE PERIOD, NORMAL DISTRIBUTION:**

Average

Q\* (Target Stock Level) = or or

*Order quantity* = or *Order quantity = Q\* - Current Inventory*

*Pipeline Inventory* =

*Total On-Hand Inventory* =

*Net Inventory Level = On-Hand Inventory + Pipeline Inventory – Backorders*

*Average Cycle Inventory = / 2*

*Average Total Inventory = Average Cycle Inventory +SS*

*Average Flowtime of Inventory =*

*Average Inventory = , \**where include the pipeline stock only when you own it.

*Total Inventory* = *, \**where include the pipeline stock only when you own it.

## **Formulae DISCRETE DISTRIBUTION:**

Lowest inventory such that:

Average

## **Formulae MULTIPLE LOCATIONS:**

Decentralised, meaning all locations have their own stock, where k is the number of locations

SS decentralised = or

Q\* dencentralised = or Q\*

Centralised, meaning all locations share a stock, where k is the number of locations

Q\*

**Delayed Differentiation**

Delayed differentiation, where k is the number of products

or

# Week 5 Part 2: Inventory Management: Replenishable Inventory

**Definitions & Denotations:**

Key assumptions: constant demand stream, constant set-up cots, constant annual holding cost per unit, with or without lead times

D = Demand rate (units/year)

C = Costs of purchasing/producing a unit ($/unit)

S = Setup cost ($)

H = Annual holding costs per unit of inventory ($/unit-year), sometimes given as a % of C

(is often taken as a as a percentage of the unit cost, H = iC where I is the annual percentage holding cost)

L = Lead time

Q or EOQ = Quantity of an order (units)

T or Optimal Order Interval = The ideal time interval between placing your orders

ROP = Reorder Point

**Formulae CONTINUOUS REVIEW WITHOUT LEAD TIME:**

*Number of orders per year (units/year) =*

*Annual fixed set-up costs ($/year) =*

*Average inventory (units) =*

*Annual holding costs ($/year) =*

*Annual purchasing costs =*

*EOQ or*

When your estimates are a little bit off you will have the following ratio: , where C’ is a result of the wrong order quantity but the ratio tends to be very small, and you will not be off by much.

When your estimates for the time is a little bit off you will have the following ratio: , where T’ is a result of the wrong time estimate but the ratio tends to be very small, and you will not be off by much.

**Formulae CONTINUOUS REVIEW WITH LEAD TIME:**

or

or

# Week 6: Inventory Management Pt. 2

**Definitions:**

Service Level/Critical Ration for the WHOLE supply chain

*b* = Buy-back price

**Formula:**

Rearrange the formula to find b, the buy-back price

# Week 7: Demand Forecasting Pt. 1 (Making a Forecast with CMA)

Step-by-Step Guide for Decomposition

Step 1: Calculate the Centre Moving Average (CMA)

* Choose the window size
* Calculate the average for all values in that window, do not let the calculations overlap

Step 2: Calculate the Specific Seasonal Index (SSI)

* SSI = x / CMA \* 100
* You do not have to multiply by 100 but if you do, you must be consistent through all your calculation

Step 3: Calculate the Typcial Seasonal Index (TSI)

* Calculate the average for all SSI of a specific period
* Say, you have winter, spring, summer and autumn, you calculate the TSI by averaging all the SSI for each season respectively

Step 4: Deseasonalise the data

* You divide the value by the respective Typical Seasonal Index
* If you multiplied by 100 earlier, you now must divide by 100
* Deseasonalised data = x/TSI\*100

Step 5: Make a prediction, meaning calculate the trend

* You will be given
* Plug in your x in the linear function and calculate y
* To make the prediction for the given season you multiply y with the Typical Seasonal Index

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Value** | **CMA** | **Specific Seasonal Index** | **Typical Seasonal Index** | **Deseasonalise** | **Reseasonalise** |
| x1 |  |  |  |  |  |
| x2 |  | SSI = x2/\*100 | TSI = Average of SSI for that specific period | X2 /TSI\*100 | Trend \* TSI/100 |
| x3 |  |  |  |  |  |
| x4 |  | SSI = x4/\*100 | TSI = Average of SSI for that specific period | X4 / TSI\*100 | Trend \* TSI/100 |
| x5 |  |  |  |  |  |
| x6 |  | SSI = x6/\*100 | TSI = Average of SSI for that specific period | X6 / TSI\*100 | Trend \* TSI/100 |

# Week 8: Demand Forecasting Pt. 2 (WTP, Net Utility, Total Demand & Revenue)

**Definitions & Denotations:**

WTP = Willingness to Pay

**Formulae & Rules:**

1. Customers will always choose the option that gives them the highest net utility (D = 1)
2. Any other option will be disregarded (D = 0)
   1. When the net utility is 0, customers tend to choose an outside option
   2. Check the exam question, if this is possible
3. Tie Breaking Rule: If there is a tie for the net utility, then there is an equal probability for choosing each option (D = 0.5)

Step 1: Calculate the demand for each option

*Demand = Number of customers where WTP is >= the specific price*

Step 2: Calculate the net utilities for each option for every customer respectively

*Net Utility = WTP – Price*

Step 3: Determine the probabilities for the customers’ choice

*Net Utility > Other Net Utilities, D = 1*

*Net Utility < Other Net Utilities, D = 0*

*Net Utility = Other Net Utilities, D = 1/number of options*

Step 4: Calculate the total demand for each option, where “i” is the specific price option for the product

*Total Demand* **=**

Incorporate the proportions of customer groups, where one group is k and the other is m

*Total Demand =*

Step 5: Calculate the Total Revenue

*Total Revenue = Total Demand \* Price*

*Total Revenue =*

Conclude by choosing the price option that gives you the highest total revenue!

# Week 9: Sigma Capability

**Definitions & Denotations:**

LTL = Lower Tolerance Limit

UTL = Upper Tolerance Limit

z= Sigma Capability, the minimum z

C = Sigma Capability Index

**Formulae:**

, the higher z, the better the process quality

, the larger the index, the better

**Calculating the Desired Standard Deviation for YY% Quality (Y out of 100 Defects):**

Step 1: Calculate the z for both LTL and UTL and find the p-value for each z-score

and

and

Step 2: Calculate the probabilities of Defects and Non-Defects

and

Optional Step: If you have two components calculate the desired probability for the second component given the YY% Quality and the P(N-D)

Step 3: Calculate the required standard deviation to achieve

, where is the probability for defects on each end of the spectrum (in each tail)

, where is the probability of falling beyond either the lower tail or the upper tail

Find the z-score for

Finally, calculate the standard deviation. Tip: Use the LTL to get a positive outcome