Practice

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TUTORIAL 1: DEMAND FORECASTING

1) An electrical contractor's records during the last five weeks indicate the following number of job requests:

Week:	**1**	**2**	**3**	**4**	**5**
Requests:	20	22	18	21	22

Predict the number of requests for week 6 using each of these methods:

a) Naïve
b) Four-week moving average
c) Exponential smoothing with $\alpha = 0.3$.

a) 22

b) $\frac{22+18+21+22}{4} = 20.75$

c) $F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$

$F_1 = 20$

$F_2 = 20 + 0.3(20 - 20) = 20$

$F_3 = 20 + 0.3(22 - 20) = 20.6$

$F_4 = 20.6 + 0.3(18 - 20.6) = 19.82$

$F_5 = 19.82 + 0.3(21 - 19.82) = 20.17$

$F_6 = 20.17 + 0.3(22 - 20.17) = 20.72$

Practice

2. A manager has just received an evaluation from an analyst on two potential forecasting methods. The analyst is indifferent between the two methods, saying that they should be equally accurate and in control. The demand and the forecasts using the two methods for nine periods follow:

Period:	1	2	3	4	5	6	7	8	9
Demand:	37	39	37	39	45	49	47	49	51
Method 1:	36	38	40	42	46	46	46	48	52
Method 2:	36	37	38	38	41	52	47	48	52

i. Calculate the MSE, MAD, and MAPE for each method. Does one method seem superior? Explain.
ii. Do all three measures of method errors provide the same conclusion (i.e. are they consistent) in this scenario? Do you expect consistent results in every case? Explain.
iii. In practice, either MAD, MSE, or MAPE would be employed to compute a measure of forecast errors. What factors might lead a manager to favour one?
iv. Calculate 2s control limits and construct a 2s control chart for each method and interpret them. Do you agree with the analyst?

i. $MSE = \frac{\sum (A_i - F_i)^2}{n}, MAD = \frac{\sum |e|}{n}, MAPE = \frac{\sum \left[\frac{|A_i - F_i|}{A_i} \times 100\right]}{n}$

Method	MSE	MAD	MAPE
1	3.7	1.7	4.0
2	3.8	16	3.6

Both methods have similar $MSE, MAD, MAPE$, so neither is superior.

ii. In this case, all calculations are similar, but may not be the same in other cases.

iii. MSE is more sensitive to large forecast errors, MAD is easy to calculate, $MAPE$ is easy to understand.

iv. $s_1 = \sqrt{MSE_1} = \sqrt{3.7} = 1.92, s_2 = \sqrt{MSE_2} = \sqrt{3.78} = 1.95$

Method 1: $2s$ control limits: $0 \pm 2s_1 = 0 \pm 2(1.92) \Rightarrow 0 \pm 3.8$

Method 1: $2s$ control limits: $0 \pm 2s_2 = 0 \pm 2(1.95) \Rightarrow 0 \pm 3.9$

Similar $2s$ control limits, however some errors outside limits.

Practice

3) Develop a linear trend equation for the following data on demand for white bread loaves at a bakery (using Excel is recommended).

a) Use the linear trend equation to forecast demand on days 16.

Day	Loafs
1	200
2	214
3	211
4	228
5	235
6	232
7	248
8	250
9	253
10	267
11	281
12	275
13	280
14	288
15	310

b) **The variations around the linear trend line seem to have above and below the line runs.** Therefore, use trend-adjusted exponential smoothing with and to model the bread demand. Use the first four days to estimate the initial smoothed series (use the average of the first four days) and smoothed trend (use the increase from day 1 to day 4 divided by 3). Start forecasting day 5. What is the forecast for day 16?

$\alpha = 0.3, \beta = 0.2$

a) Equation of the trend: $y = 7x + 195.47$

$D_{16} = 7(16) + 195.47 \Rightarrow D_{16} = 307.47$

b) $S_t = TAF_t + \alpha(A_t - TAF_t)$

$T_t = T_{t-1} + \beta(S_t - S_{t-1} - T_{t-1})$

$TAF_{t+1} = S_t + T_t$

$$T_4 = \frac{228 - 200}{3} = 9.33, S_4 = \frac{200 + 214 + 211 + 228}{4} = 213.25$$

Use above equations each time to get $TAF_{16} = S_{15} + T_{15} = 303.53 + 7.64 = 311.17$.

Practice

4) A gift shop in a tourist centre is open only on weekends (Friday, Saturday, and Sunday). The owner-manager hopes to improve scheduling of part-time employees by determining seasonal relatives for each of these days. Data on recent activity at the store (sales transactions per day) are shown in the following table:

	Week					
	1	2	3	4	5	6
Friday	149	154	152	150	159	163
Saturday	250	255	260	268	273	276
Sunday	166	162	171	173	176	183

a) Develop seasonal relatives for each day using the centered moving average method.

b) Deseasonalize the data, fit an appropriate model to the deseasonalized data, project three days ahead, and reseasonalize the projections to forecast the sales transactions for each day, Friday to Sunday, of next week.

a) Seasonal relatives are shown as the values in the *adjusted* row:

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a

Week	Day	Sales	CMA_3	$Sales/CMA_3$
1	Fri	149		
	Sat	250	188.3	1.327
	Sun	166	190.0	0.874
2	Fri	154	191.7	0.803
	Sat	255	190.3	1.340
	Sun	162	189.7	0.854
3	Fri	152	191.3	0.794
	Sat	260	194.3	1.338
	Sun	171	193.7	0.883
4	Fri	150	196.3	0.764
	Sat	268	197.0	1.360
	Sun	173	200.0	0.865
5	Fri	159	201.7	0.788
	Sat	273	202.7	1.347
	Sun	176	204.0	0.863
6	Fri	163	205.0	0.795
	Sat	276	207.3	1.331
	Sun	183		

CMA$_3$ → no. of seasons
Fri, Sat, Sun

$250/188.3 = 1.327$

$276/207.3 = 1.331$

Next step: calculate avg. of Sales/CMA$_3$ for each season

	Fri	Sat	Sun	
Week 1		1.327	0.874	
Week 2	0.803	1.340	0.854	
Week 3	0.794	1.338	0.883	
Week 4	0.764	1.360	0.865	
Week 5	0.788	1.347	0.863	
Week 6	0.795	1.331		sum Σ Avg$_s$
avg	0.789	1.341	0.868	2.997
adjusted	0.790	1.342	0.868	3.000

Adjusted SRs

SR

$$\text{Adjusted SR} = \text{Avg}_s \times \frac{\text{No. of Seasons}}{\Sigma \text{Avg}}$$

$$= .789 \times \frac{3}{2.997}$$

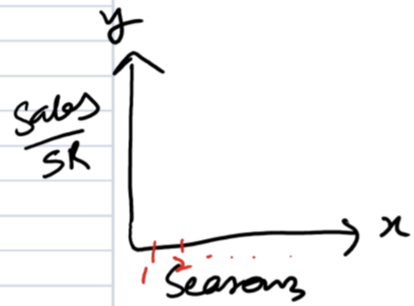
$$= 0.790$$

Practice

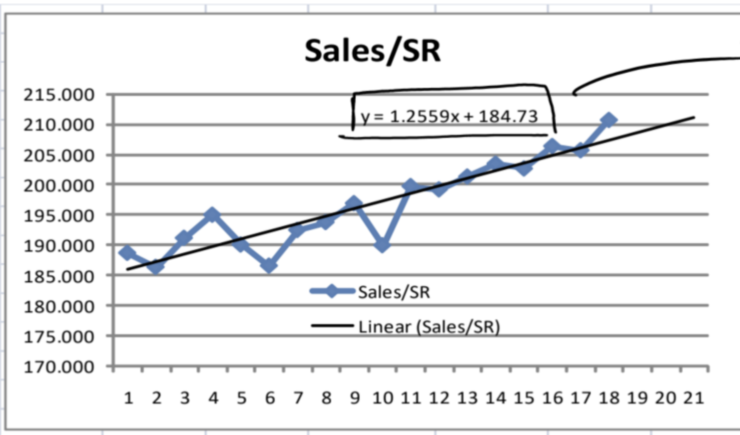
b) Deseasonalized data is shown as the values in the $Sales/SR$ column:

Deseasonalizing $= \frac{\text{Sales}}{\text{SR}}$

b					
Week	Day	Sales	SR	Sales/SR	
1	Fri 1	149	0.790	188.662	
	Sat 2	250	1.342	186.320	
	Sun 3	166	0.868	191.145	
2	Fri 4	154	0.790	194.993	
	Sat 5	255	1.342	190.047	
	Sun	162	0.868	186.539	
3	Fri	152	0.790	192.461	
	Sat	260	1.342	193.773	
	Sun	171	0.868	196.902	
4	Fri	150	0.790	189.928	
	Sat	268	1.342	199.735	
	Sun	173	0.868	199.205	
5	Fri	159	0.790	201.324	
	Sat	273	1.342	203.462	
	Sun	176	0.868	202.660	
6	Fri	163	0.790	206.389	
	Sat	276	1.342	205.697	
	Sun	183	0.868	210.720	



The model, projection, and reseasonalized data is shown below:



$x = 19$

$y = 1.2559(19) + 184.73$

$= 208.592$

			Trend fcst	forecast
7	Fri	19	208.592	164.740
	Sat	20	209.848	281.569
	Sun	21	211.104	183.333

Final Step:

* Reseasonalize the trend forecasted values from model.

* Reseasonalizing

$=$ TF value $\times$ SR

$= 208.592 \times 0.790$

$= 164.740$

Practice

TUTORIAL 2: CAPACITY PLANNING AND FACILITY LAYOUT

1. Determine the utilization and the efficiency for each of these situations:

   a. A loan processing operation that processes an average of 7 loans per day. The operation has a design capacity of 10 loans per day and an effective capacity of 8 loans per day.

   b. A furnace repair team that services an average of four furnaces a day if the design capacity is six furnaces a day and the effective capacity is five furnaces a day.

   c. Would you say that systems that have higher efficiency ratios than other systems will always have higher utilization ratios than those other systems? Explain.

a. $actual\ output = 7, design\ capacity = 10, effective\ capacity = 8$

$$utilization = \frac{actual\ output}{design\ capacity} = \frac{7}{10} = 70\%$$

$$efficiency = \frac{actual\ output}{effective\ capacity} = \frac{7}{8} = 87.5\%$$

b. $actual\ output = 4, design\ capacity = 6, effective\ capacity = 5$

$$utilization = \frac{actual\ output}{design\ capacity} = \frac{4}{6} = 66\%$$

$$efficiency = \frac{actual\ output}{effective\ capacity} = \frac{4}{5} = 80\%$$

c. No because utilization depends on design capacity while efficiency depends on effective capacity.

Practice

2. Corner Tavern is a small-town bar that sells only bottled beer. The average price of a bottle of beer at the tavern is $3.00 and the average cost of bottle of beer to the tavern is $1.00. The tavern is open every night. One bartender and two to three waitresses are on duty each night. The fixed costs (salaries, rent, tax, utilities, etc.) total $260,000 per year.

   a. The owner wishes to know how many bottles of beer the tavern must sell during the year to start making profit.
   b. What is the revenue at the break-even quantity found in part a.
   c. The owner thinks $50,000 is a reasonable annual profit. How many bottles of beer should the tavern sell to make $50,000 profit?
   d. An available option is to open the tavern earlier on the weekends. The attraction would be discount of $0.50 off the regular price. The extra salaries of waitresses and bartender for the whole year are estimated to be $30,000. How many extra bottles of beer must the tavern sell in order to break-even in this option?

a. $average\ price\ (R) = \$3.00, average\ cost\ (v) = \$1.00, fixed\ cost\ (FC) = \$260{,}000$

$$Q_{BEP} = \frac{FC}{R - v} = \frac{260{,}000}{3 - 1} = 130{,}000\ bottles$$

b. $TR_{BEP} = Q_{BEP} \cdot R = 130{,}000 \cdot 3 = \$390{,}000$

c. $Q = \frac{P+FC}{R-v} = \frac{50{,}000+260{,}000}{3-1} = 155{,}000\ bottles$

d. $Q'_{BEP} = \frac{FC'}{R'-v} = \frac{30{,}000}{2.5-1} = 20{,}000\ bottles$

Practice

3. A producer of pottery is considering the addition of a new plant to absorb the backlog of demand that now exists. The primary location being considered will have fixed costs of \$9,200 per month and variable costs of 70 cents per unit produced. Each item is sold to retailers at a price that averages 90 cents.
   a. What volume per month is required in order to break even?
   b. What profit would be realized on a monthly volume of 61,000 units? 87,000 units?
   c. What volume is needed to obtain a profit of \$16,000 per month?
   d. What volume is needed to provide a revenue of \$23,000 per month?
   e. Plot the total cost and total revenue lines.

a. $FC = \$9{,}200, v = 70\ cents \rightarrow \$0.7, R = 90\ cents \rightarrow \$0.9$

$$Q_{BEP} = \frac{FC}{R - v} = \frac{9{,}200}{0.9 - 0.7} = 46{,}000\ units$$

b. $P = Q(R - v) - FC$

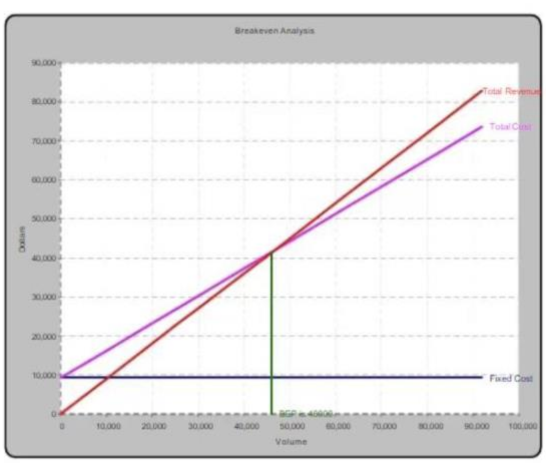
$$P_1 = 61{,}000(0.9 - 0.7) - 9{,}200 = \$3{,}000$$

$$P_2 = 87{,}000(0.9 - 0.7) - 9{,}200 = \$8{,}200$$

c. $Q = \frac{P+FC}{R-v} = \frac{16{,}000+9{,}200}{0.9-0.7} = 126{,}000\ units$

d. $Q = \frac{P+FC}{R-v} = \frac{23{,}000+9{,}200}{0.9-0.7} = 161{,}000\ units$

e. Plot of $total\ cost\ (TC) = 0.7Q + 10{,}000$ and $total\ revenue\ (TR) = 0.9Q$ lines:



Practice

TUTORIAL 3: PROCESS DESIGN AND FACILITY LAYOUT

1) An assembly line with 17 tasks is to be balanced. The longest task is 2.4 minutes, and the total time for all tasks is 18 minutes. The line will operate for 450 minutes per day.
   a. What are the minimum and maximum cycle times?
   b. What range of output is theoretically possible for the line?
   c. What is the minimum number of workstations needed if the maximum output rate is to be sought?
   d. What cycle time will provide an output rate of 125 units per day?
   e. What output potential will result if the cycle time is (1) 9 minutes? (2) 15 minutes?

$OT = 450\ minutes$

a. $Minimum\ cycle\ time = length\ of\ longest\ task = 2.4\ minutes$

$Maximum\ cycle\ time = \sum task\ times = 18\ minutes$

b. $At\ 2.4\ min: \frac{450}{2.4} = 187.5\ units$

$At\ 18\ min: \frac{450}{18} = 25\ units$

c. $N = \frac{D \times \sum t}{OT} = \frac{187.5 \times 18}{450} = 7.5 \rightarrow 8$

d. $Output = \frac{OT}{CT}$, Solving for CT: $CT = \frac{450}{125} = 3.6\ minutes/cycle$

e. Potential output:

(1) $CT = 9\ min \rightarrow \frac{OT}{CT} = \frac{450}{9} = 50\ units$

(2) $CT = 15\ min \rightarrow \frac{450}{15} = 30\ units$

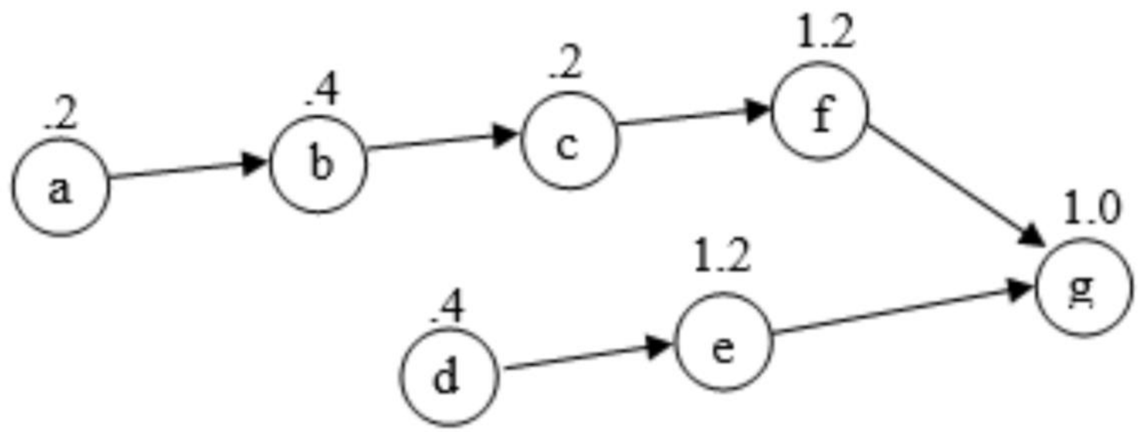
Practice

2) As part of a major plant renovation project, the industrial engineering department has been asked to balance a revised assembly operation to achieve an output of 240 units per eight-hour day. Task times and precedence relationships are as follows:

   a. Draw the precedence diagram.
   b. Determine the minimum cycle time, the maximum cycle time, and the calculated cycle time.
   c. Determine the minimum number of stations needed.
   d. Assign tasks to workstations on the basis of greatest number of following tasks. Use longest processing time as a tiebreaker. If ties still exist, assume indifference in choice.
   e. Compute the percentage of idle time for the assignment in part *d*.

Task	Duration (minutes)	Immediate Predecessor
a	0.2	—
b	0.4	a
c	0.2	b
d	0.4	—
e	1.2	d
f	1.2	c
g	1.0	e, f

a. Precedence diagram:



b. $Minimum\ cycle\ time = maximum\ task\ time = 1.2\ minutes$

$Maximum\ cycle\ time = 0.2 + 0.4 + 0.2 + 0.4 + 1.2 + 1.2 + 1.0 = 4.6\ minutes$

$CT = \frac{OT}{output} = \frac{480\ min/day}{240\ units/day} = 2\ minutes$

c. $N = \frac{\sum t}{CT} = \frac{4.6}{2.0} = 2.3 \rightarrow 3\ stations$

d. Assign tasks to workstations:

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Task	Number of following tasks
A	4
B	3
C	2
D	2
E	1
F	1
G	0

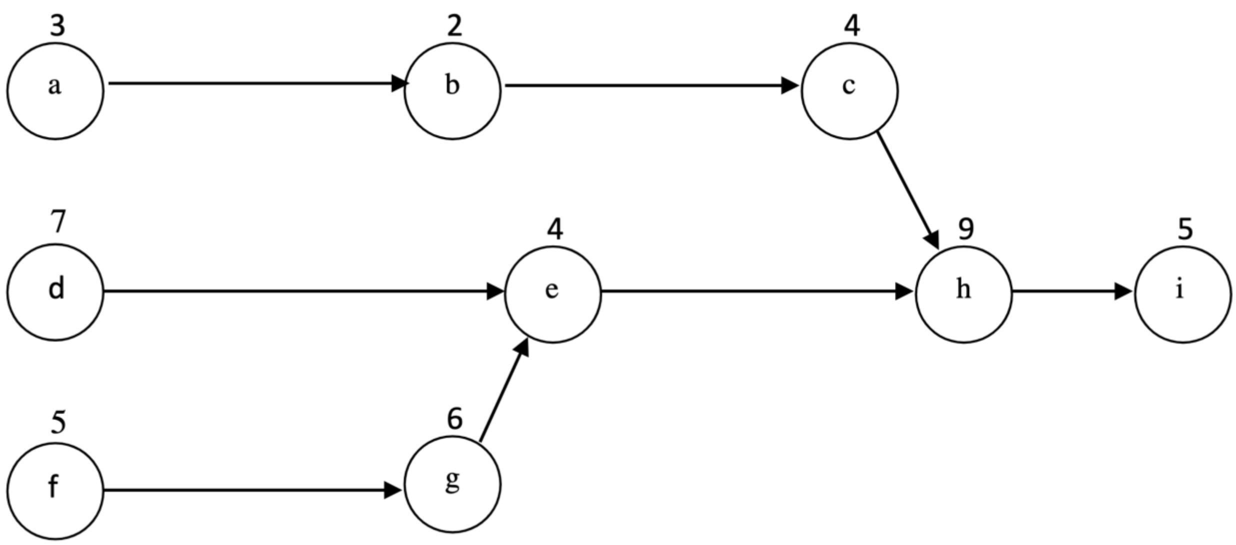
Assembly Line Balancing Table (CT = 2 minutes)

Work Station	Assigned Task	Task Time	Time Remaining	Feasible tasks Remaining
I	A	0.2	1.8	B,D
	B	0.4	1.4	C, D
	D	0.4	1.0	C
	C	0.2	0.8	E
II	E	1.2	0.8	F
III	F	1.2	0.8	G
IV	G	1.0	1.0	–

e. $Idle\ percent = \frac{0.8+0.8+0.8+1.0}{(4)(2)} = \frac{3.4}{8.0} = 42.5\%$

Practice

3) A manager wants to assign tasks to workstations in order to achieve an hourly output rate of four units. The department uses a working time of 56 minutes per hour.
   - **a.** Assign the tasks shown in the following precedence network (times are on the nodes and are in minutes) to workstations using the following heuristic rules: (i) "Assign the task with the largest positional weight." (ii) Tiebreaker: "Assign the task with the longest time." If a tie still exists, choose randomly.
   - **b.** What is the efficiency?
   - **c.** Calculate the percentage idle time for the line.



a. $Desired\ output = 4\ units/hour$

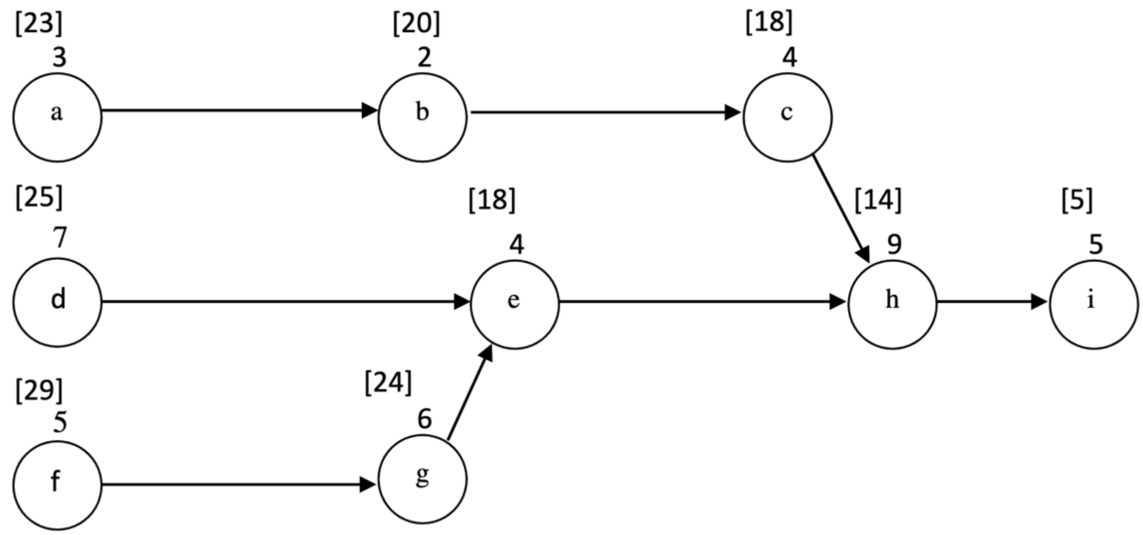
$Operating\ time = 56\ minutes/hour$

$CT = \frac{Operating\ time}{Desired\ output} = \frac{56\ minutes/hour}{4\ units/hour} = 14\ minutes/unit$

$N_{min} = \frac{\sum t}{CT} = \frac{3+2+4+7+4+5+6+9+5}{14} = 3.21 \rightarrow 4\ workstations$

Positional weights:

Practice



Station	Time Remaining	Feasible Remaining	Assigned Task	Task Time	Idle
1	14	a, d, f	f	(5)	
	9	a, d, g	d	(7)	
	2	a, g	--		2
2	14	a, g	g	(6)	
	8	a, e	a	(3)	
	5	b, e	b	(2)	
	3	c, e	--		3
3	14	c, e	c*, e	(4)	
	10	e	e	(4)	
	6	h	--		6
4	14	h	h	h (9)	
	5	i	i	i (5)	0
					11

b. $Efficiency = 1 - \frac{Total\ idle\ time}{CT \times \#\ of\ stations} = 1 - \frac{11}{14 \times 4} = 80.4\%$

c. $Percentage\ idle\ time = \frac{\sum(idle\ time)}{N \times CT} \times 100 = \frac{11}{4 \times 14} \times 100 = 19.64\%$

4. Fixed-Position Layout: Product or project remains stationary, and workers, materials, and equipment are moved as needed.

5. Cycle Time: The maximum time allowed at each workstation to complete its set of tasks on a unit.

Practice

TUTORIAL 4: QUALITY MANAGEMENT AND STATISTICAL CONTROL

1) An air-conditioning repair department manager has compiled on the primary reason for 41 service calls during the previous week, as shown. Using the data, make a check sheet for the problem types for each customer type, and then construct a Pareto chart for each type of customer.

Job Number	Problem/Customer Type	Job Number	Problem/Customer Type	Job Number	Problem/Customer Type
1	F/R	15	F/C	29	O/C
2	O/R	16	O/C	30	N/R
3	N/C	17	W/C	31	N/R
4	N/R	18	N/R	32	W/R
5	W/C	19	O/C	33	O/R
6	N/R	20	F/R	34	O/C
7	F/R	21	F/R	35	N/R
8	N/C	22	O/R	36	W/R
9	W/R	23	F/R	37	O/C
10	N/R	24	N/C	38	O/R
11	N/R	25	F/R	39	F/R
12	F/C	26	O/R	40	N/R
13	N/R	27	W/C	41	O/C
14	W/C	28	O/C		

Key:

Problem Type

N: Noisy

F: Equipment Failure

W: Runs warm

O: Odour

Customer Type

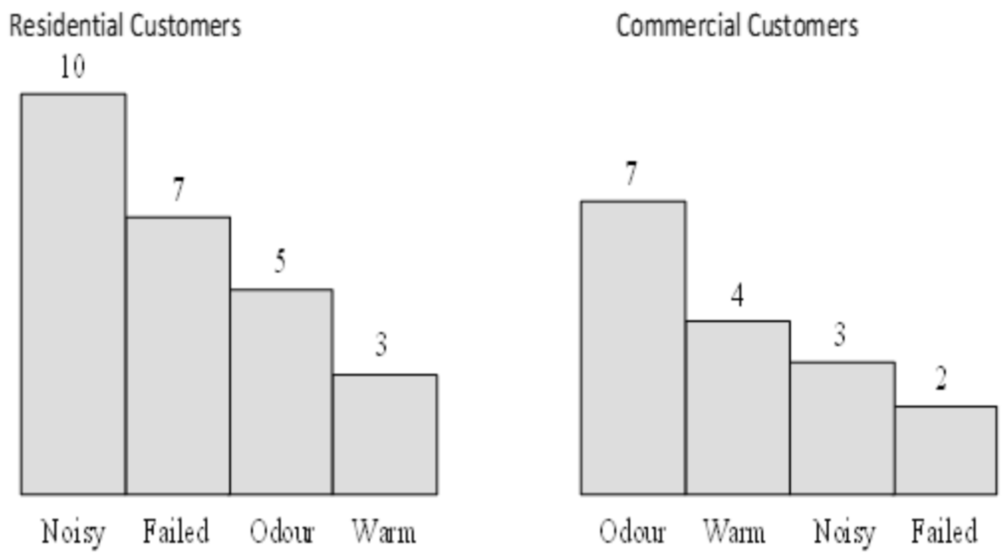
C: Commercial customer

R: Residential customer

Practice

Check sheet

Equipment Problem					
Customer Type	*Noisy*	*Failed*	*Odour*	*Warm*	*Totals*
Residential	10	7	5	3	25
Commercial	3	2	7	4	16
Totals	*13*	*9*	*12*	*7*	*41*



Practice

2) Prepare a run chart for the number of defective computer monitors produced in a plant show below. Workers are given a 15-minute break at 10:15 a.m. and 3:15 p.m., and a lunch break at noon. What can you conclude?

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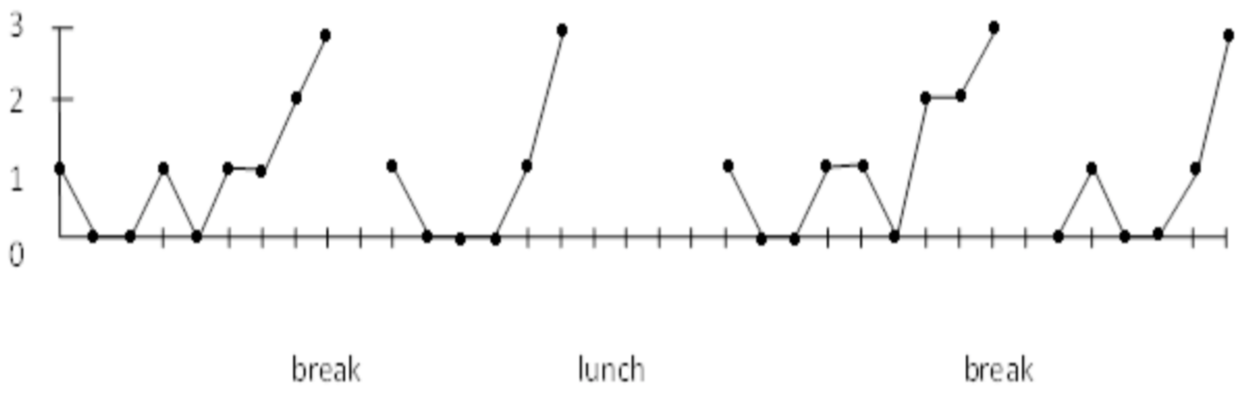
Interval start time	Number of Defects	Interval start time	Number of Defects	Interval start time	Number of Defects
8:00	1	10:45	0	2:15	0
8:15	0	11:00	0	2:30	2
8:30	0	11:15	0	2:45	2
8:45	1	11:30	1	3:00	3
9:00	0	11:45	3	3:30	0
9:15	1	1:00	1	3:45	1
9:30	1	1:15	0	4:00	0
9:45	2	1:30	0	4:15	0
10:00	3	1:45	1	4:30	1
10:30	1	2:00	1	4:45	3



Increasing pattern of errors just before the break times, lunch, and the end of the shift.

Practice

3) Prepare a scatter diagram for each of the following pairs of variables and then express in words the apparent relationship between the two variables. Put the first variable on the horizontal axis and the second variable on the vertical axis.

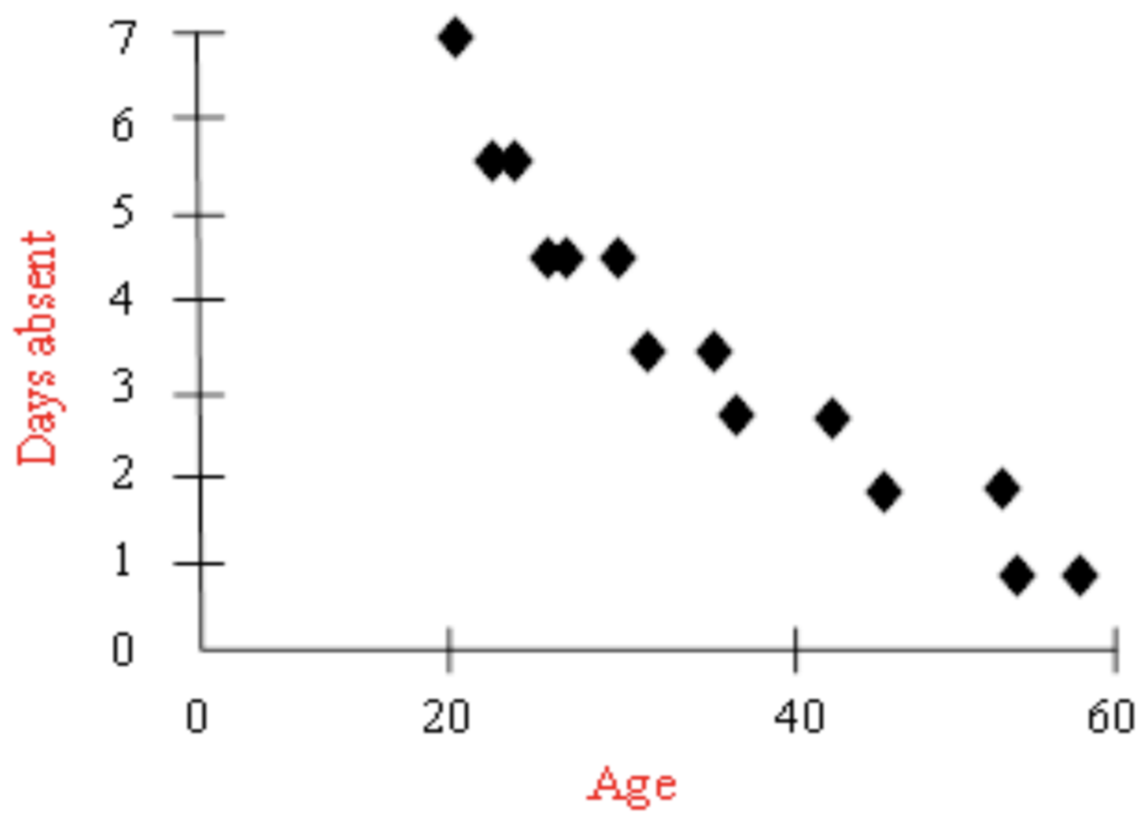
a.

Age	24	30	22	25	33	27	36	58	37	47	54	28	42	55
Days Absent	6	5	7	6	4	5	4	1	3	2	2	5	3	1

b.

Temperature	18	17	22	19	28	14	24	30	25	18	26
Error Rate	1	2	0	0	3	3	1	5	2	1	3

a. Scatter diagram for a:



Age and days absent are inversely related. Older employees missed fewer days.

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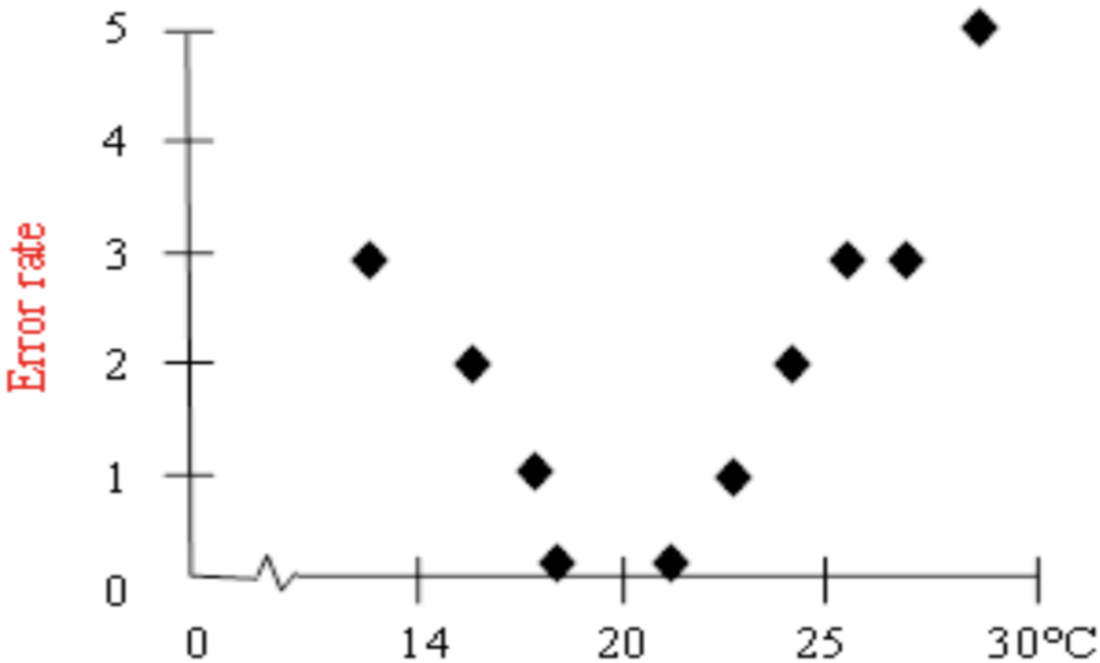
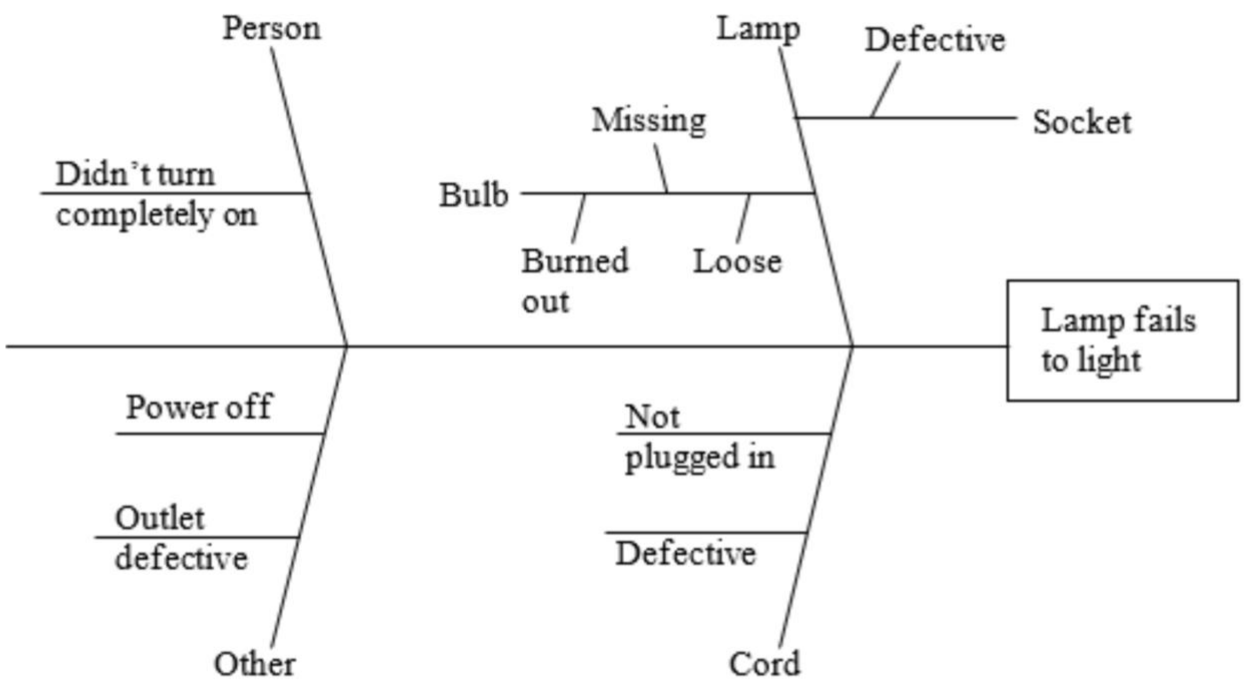
b. Scatter diagram for b:



Error rate is non-linearly related to temperature. It increases in colder or hotter temperatures. The lowest error rate occurs around $20°C$.

Practice

4) Suppose that a table lamp fails to light when turned on. Prepare a simple cause-and-effect diagram to analyze possible causes.



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5) An automatic filling machine is used to fill 2-litre bottles of cola. The machine's output is known to be approximately Normal with a mean of 2.0 litres and a standard deviation of 0.01 litres. Output is monitored using means of samples of five observations.

a. Determine the upper and lower control limits that will include roughly 95.5 percent of sample means.

b. If the means for 6 samples are 2.005, 2.001, 1.998, 2.002, 1.995, and 1.999, is the process in control?

$$\mu = 2.0\ litres, \sigma = 0.01\ litres, n = 5$$

a. Control limits: $\mu \pm z\frac{\sigma}{\sqrt{n}}$

   $95.44\% \rightarrow z = 2$

   $UCL = 2.0 + 2\frac{0.01}{\sqrt{5}} = 2.009\ litres$

   $LCL = 2.0 - 2\frac{0.01}{\sqrt{5}} = 1.991\ litres$

b. Yes, because they all fall within the control limits and the pattern of data seems random.

Practice

6) Computer upgrades have a nominal time of 80 minutes. Samples of five observations each have been taken, and the results are as listed. Using factors from Table 10.3 , determine upper and lower control limits for mean and range charts, and decide if the process is in control.

	SAMPLE						
	1	**2**	**3**	**4**	**5**	**6**	
	79.2	80.5	79.6	78.9	80.5	79.7	
	78.8	78.7	79.4	79.4	79.6	80.6	
	80.0	81.0	80.4	79.7	80.4	80.5	
	78.4	80.4	80.3	79.4	80.8	80.0	
	81.0	80.1	80.8	80.6	78.8	81.1	**Grand**
Mean	79.5	80.14	80.10	79.60	80.02	80.38	79.95
Range	2.6	2.3	1.4	1.7	2.0	1.4	1.90

$$For\ n = 5, from\ Table\ 10 - 3: A_2 = 0.58, D_3 = 0, D_4 = 2.11\ (page\ 37\ of\ lecture\ notes)$$

Mean control limits:

$$\bar{\bar{X}} \pm A_2\bar{R} = 79.95 \pm 0.58(1.90) = 79.95 \pm 1.1$$

$$UCL = 81.05, LCL = 78.85$$

Range control limits:

$$UCL = D_4\bar{R} = 2.11(1.90) = 4.009$$

$$LCL = D_3\bar{R} = 0(1.90) = 0$$

Process is in control because all sample means and ranges fall within respective control limits.

7. Type I error concludes a process has changed when it actually has not, and Type II error concludes a process is in control when it is actually not.

Practice

TUTORIAL 5: SUPPLY CHAIN MANAGEMENT

1) Given the following data, determine the total annual cost of making and buying from each vendor A and vendor B. Estimated demand is 15,000 units a year. Which alternative is best?

	Make	Vendor A	Vendor B
Variable cost per unit	$8	$11	$10
Annual fixed cost	$20,000	$0	$5,000 (annual charge)

$$Total\ Annual\ Cost = Fixed\ Cost + Variable\ Cost\ Per\ Unit \times Annual\ Quantity$$

$$Make: \$20{,}000 + \$8 \times 15{,}000 = \$140{,}000$$

$$Vendor\ A: \$0 + \$11 \times 15{,}000 = \$165{,}000$$

$$Vendor\ B: \$5{,}000 + \$10 \times 15{,}000 = \$155{,}000$$

Thus, making the products yourself would be the best alternative.

2) Given the following data, determine the total annual cost of making with each of process A and B and of buying. Estimated demand is 10,000 units a year. Which alternate is best?

	Make		
	Process A	**Process B**	**Buy**
Variable cost per unit	$50	$52	$51
Annual fixed cost	$40,000	$36,000	
Transportation cost per unit			$2

$$Process\ A: \$40{,}000 + \$50 \times 10{,}000 = \$540{,}000$$

$$Process\ B: \$36{,}000 + \$52 \times 10{,}000 = \$556{,}000$$

$$Buy: \$51 \times 10{,}000 + \$2 \times 10{,}000 = \$530{,}000$$

Thus, buying would have the lowest total annual cost.

3) For the previous problem, suppose that the operations manager has said that it would be possible to achieve a 10 percent reduction in the fixed cost of Process B and a 10 percent reduction in B's variable cost per unit. Would that be enough to change your answer if the estimated annual cost to achieve those savings was $8,000? Explain.

$$New\ Process\ B: \$36{,}000 \times 0.9 + \$8{,}000 + \$52 \times 0.9 \times 10{,}000 = \$508{,}400$$

Yes, the amount is less than buying, therefore make using Process B.

Practice

4)

a. Determine which delivery alternative would be most economical for 80 boxes of parts. Each box costs \$200 and annual holding cost is 30 percent of cost. Assume 365 days per year. Freight costs are:

Alternative	Freight Cost (for all 80 boxes)
Overnight	\$300
Two-day	\$260
Six-day	\$180

b. For what range of unit cost for a box would each delivery alternative be least costly?

$$H = 0.30 \times 80\ boxes \times \$200 = \$4{,}800$$

a. $Overnight: \$300 + \$4800 \times \frac{1}{365} = \$313.15$

$Two\ Day: \$260 + \$4{,}800 \times \frac{2}{365} = \$286.30$

$Six\ Day: \$180 + \$4{,}800 \times \frac{6}{365} = \$258.90$

Six-day alternative is cheapest.

b. $Let\ X = cost\ per\ box$. Then $H = 24X$, and the total costs will be:

$$Overnight: \$300 + \frac{24}{365}X$$

$$Two\ Day: \$260 + \frac{48}{365}X$$

$$Six\ Day: \$180 + \frac{144}{365}X$$

Overnight cheapest:

$$300 + \frac{24}{365}X < 260 + \frac{48}{365}X \Rightarrow X > \$608.33$$

$$300 + \frac{24}{365}X < 180 + \frac{144}{365}X \Rightarrow X > \$365.00$$

Two-day cheapest:

$$260 + \frac{48}{365}X < 300 + \frac{24}{365}X \Rightarrow X < \$608.33$$

Practice

$$260 + \frac{48}{365}X < 180 + \frac{144}{365}X \Rightarrow X > \$304.17$$

Six-day cheapest:

$$180 + \frac{144}{365}X < 300 + \frac{24}{365}X \Rightarrow X < \$365.00$$

$$180 + \frac{144}{365}X < 260 + \frac{48}{365}X \Rightarrow X < \$304.17$$

Overnight is cheapest if $unit\ cost > \$608.33$

Two-day cheapest if $\$304.17 < unit\ cost < \$608.33$

Six-day cheapest if $unit\ cost < \$304.17$

Practice

5) Pratt & Whitney, a major aircraft engine manufacturer, wants to re-evaluate the transportation mode it uses to send unfinished parts to its joint-venture facility in Chengdu, China. Annual demand is 2,900 units. At present the company uses air freight. It takes approximately six days from Los Angeles to Chengdu (including pickup and delivery and customs delays). There are 20 parts in a lot, each weighing 30 kilograms. The air freight cost per part is $90. The pickup and delivery charges at origin and destination add up to $15 per part.

The alternative is to use an ocean liner to ship the parts to Shanghai and from there to either use a truck or a train (a 2,000 km distance). The ocean freight for this lot size will cost $30 per part and will take 15 days. The truck from Shanghai to Chengdu will cost $20 per part and will take six days (including pickup and delivery and customs delays). Transportation by rail will cost $15 per part and will take 14 days (including pickup and delivery and customs delays). In addition, for rail there is a $10 per part charge for pickup and delivery.

The company's inventory holding cost rate is 12 percent per year, and the value of each part is $1,000. Assume 365 days per year.

Due to variability of lead times, at the destination, safety stocks of 60, 210, and 290 units will be kept if air, ship and truck, and ship and train are used, respectively. Determine the cheapest (total freight, delivery, and in-transit and safety holding cost) mode of transportation for these parts.

Hint: The value of a part in Chengdu for calculating the safety-stock holding cost should include the freight cost.

Mode	**Duration ($days$)**	**Cost ($) Per Part**
Air	6	$90+15=105$
Ocean, Truck	$15+6=21$	$30+20=50$
Ocean, Train	$15+14=29$	$30+15+10=55$

Mode	**Annual Freight & Delivery Costs**
Air	$\$105 \times 2{,}900 = \$304{,}500$
Ocean, Truck	$\$50 \times 2{,}900 = \$145{,}000$
Ocean, Train	$\$55 \times 2{,}900 = \$159{,}500$

Practice

Mode	Annual In-Transit Holding Costs
Air	$\$1{,}000 \times 0.12 \times \frac{6}{365} \times 2{,}900 = \$5{,}720.55$
Ocean, Truck	$\$1{,}000 \times 0.12 \times \frac{21}{365} \times 2{,}900 = \$20{,}021.92$
Ocean, Train	$\$1{,}000 \times 0.12 \times \frac{29}{365} \times 2{,}900 = \$27{,}649.32$

Mode	Annual Safety Stock Holding Costs
Air	$60 \times (\$1{,}000 + \$105) \times 0.12 = \$7{,}956$
Ocean, Truck	$210 \times (\$1{,}000 + \$50) \times 0.12 = \$26{,}460$
Ocean, Train	$290 \times (\$1{,}000 + \$55) \times 0.12 = \$36{,}714$

Mode	Annual Total Cost
Air	$\$304{,}500 + \$5{,}720.55 + \$7{,}956 = \$318{,}176.55$
Ocean, Truck	$\$145{,}000 + \$20{,}021.92 + \$26{,}460 = \$191{,}481.92$
Ocean, Train	$\$159{,}500 + \$27{,}649.32 + \$36{,}714 = \$223{,}863.32$

The cheapest mode of transportation for these parts is by ocean and truck.

Practice

TUTORIAL 6: INVENTORY MANAGEMENT I

1)

A large bakery buys flour in 25-pound bags. The bakery uses an average of 1,215 bags a year. Preparing an order and receiving a shipment of flour involves a cost of $10 per order. Annual carrying costs are $75 per bag.

a. Determine the economic order quantity.
b. What is the average number of bags on hand?
c. How many orders per year will there be?
d. Compute the total cost of ordering and carrying flour.
e. If holding costs were to increase by $9 per year, how much would that affect the minimum total annual cost?

$$D = 1{,}215\ bags\ a\ year, S = \$10\ per\ order, H = \$75\ per\ bag$$

a. $Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(1{,}215)(10)}{75}} = \sqrt{324} = 18\ bags$

The EOQ of the bakery is 18 bags.

b. $Average\ inventory\ level = \frac{Q_0}{2} = \frac{18}{2} = 9\ bags$

The average number of bags on hand is 9.

c. $Orders\ per\ year = \frac{Annual\ demand}{Economic\ order\ quantity} = \frac{1{,}215}{18} = 67.5\ bags$

The number of orders per year is 67.5 bags.

d. $Total\ cost = Carrying\ cost + Ordering\ cost$

$Total\ cost = \frac{Q_0}{2}H + \frac{D}{Q_0}S = \frac{18}{2} \times 75 + \frac{1{,}215}{18} \times 10 = \$1{,}350$

Total cost of ordering and holding flour is $1,350.

e. $New\ carrying\ cost = \$75 + \$9 = \$84$

$Q_0 = \sqrt{\frac{2(1{,}215)(10)}{84}} = \sqrt{289.28} = 17.27\ bags$ (round to 17 bags)

$New\ total\ cost = \frac{17}{2} \times 84 + \frac{1{,}215}{17} \times 10 = \$1{,}428.70$

$Affect\ in\ total\ cost = New\ total\ cost - Old\ total\ cost$

$Affect\ in\ total\ cost = \$1{,}428.70 - \$1{,}350 = \$78.70$

The affect in total cost is $78.70.

Practice

2)
A produce distributor uses 800 packing crates a month, which it purchases at a cost of $10 each. The manager has assigned an annual carrying cost of 35 percent of the purchase price per crate. Ordering costs are $28. Currently the manager orders once a month. How much could the firm save annually in ordering and carrying costs by using the EOQ?

$$Crates/month = 800, Purchase\ cost/crate = \$10, H = 35\%\ of\ purchase\ cost, S = \$28$$

Step 1: Calculate the annual demand:

$$D = Monthly\ demand \times 12 = 800 \times 12 = 9{,}600\ crates$$

Step 2: Calculate carrying cost:

$$H = 0.35 \times \$10 = \$3.5$$

Step 3: Calculate the EOQ:

$$Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(9{,}600)(28)}{3.5}} = \sqrt{153{,}600} = 391.92 \approx 392\ crates$$

Step 4: Calculate the total cost when EOQ is ordered:

$$Total\ cost = Carrying\ cost + Order\ cost = \frac{Q}{2}H + \frac{D}{Q}S$$

$$Total\ cost_{EOQ} = \frac{392}{2} \times 3.5 + \frac{9{,}600}{392} \times 28 = 686 + 685.7 = \$1{,}372$$

Step 5: Calculate the total cost when 800 units are ordered per month:

$$Total\ cost_{800} = \frac{800}{2} \times 3.5 + \frac{9{,}600}{800} \times 28 = 1{,}400 + 336 = \$1{,}736$$

Step 6: Calculate the savings when EOQ is used:

$$Amount\ saved = Total\ cost_{800} - Total\ cost_{EOQ} = \$1{,}736 - \$1{,}372 = \$364$$

The amount that will be saved using EOQ is $\$364$.

Practice

3)

The Friendly Sausage Factory (FSF) can produce hot dogs at a rate of 5,000 per day. FSF supplies hot dogs to local restaurants at a steady rate of 250 per day. The cost to prepare the equipment for producing hot dogs is $66. Annual holding costs are 45 cents per hot dog. The factory operates 300 days a year. Find:
a. The optimal run size.
b. The number of runs per year.
c. The length (in days) of a run.

$$p = 5{,}000/day, d = 250/day, S = \$66, H = \$0.45/hot\ dog, days/year = 300$$

a. $D = usage\ rate \times \#\ of\ working\ days = 250 \times 300 = 75{,}000\ hot\ dogs/year$

$$Q_p = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-d}} = \sqrt{\frac{2(75{,}000)(66)}{0.45}}\sqrt{\frac{5{,}000}{5{,}000-250}} = 4812.37 \approx 4{,}812$$

The optimal run size is 4,812.

b. $Number\ of\ runs\ per\ year = \frac{D}{Q_p} = \frac{75{,}000}{4{,}812} = 15.59\ runs\ per\ year$

The number of runs per year is 15.59.

c. $Number\ of\ days\ of\ a\ run = \frac{Q_p}{p} = \frac{4{,}812}{5{,}000} = 0.96\ days$

The number of days to produce optimal run capacity is 0.96 days.

Practice

4)

A chemical firm produces sodium bisulfate in 100-pound bags. Demand for this product is 20 tons per day. The capacity for producing the product is 50 tons per day. Setup costs \$100, and storage and handling costs are \$5 per ton a year. The firm operates 200 days a year. (*Note:* 1 ton = 2,000 pounds.)
a. How many bags per run are optimal?
b. What would the average inventory be for this lot size?
c. Determine the approximate length of a production run, in days.
d. About how many runs per year would there be?

e. How much could the company save annually if the setup cost could be reduced to \$25 per run?

$$d = 20\ tons/day, p = 50\ tons/day, S = \$100, H = \$5/ton/year, operation\ days = 200$$

a. $D = d \times operation\ days = 20\ tons/day \times 200\ days = 4{,}000\ tons$

   Hence, $D = 4{,}000$ tons.

b. Step 1: Calculate the optimum quantity using the EPQ formula:

   $$Q = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-d}} = \sqrt{\frac{2(4{,}000)(100)}{5}}\sqrt{\frac{50}{50-20}} = 516.4\ tons$$

   Step 2: Calculate the maximum inventory:

   $$I_{MAX} = \frac{Q}{p}(p-d) = \frac{516.4}{50}(50-20) = 309.84\ tons$$

   Step 3: Calculate the average inventory:

   $$Average\ inventory = \frac{I_{MAX}}{2} = \frac{309.84}{2} = 154.92$$

   The average inventory for this lot size is 154.92.

c. $Length\ of\ production\ time = \frac{Q}{p} = \frac{516.4}{50} = 10.33\ days$

   The approximate length of a production run is 10.33 days.

d. $Production\ runs\ per\ year = \frac{D}{Q} = \frac{4{,}000}{516.4} = 7.75\ runs \approx 8\ runs$

   The number of runs per year are about 8 runs.

e. Step 1: Calculate the total cost of production at the current setup cost:

   $$Total\ cost = \frac{I_{MAX}}{2} \times H + \frac{D}{Q} \times S = \frac{309.84}{2} \times \$5 + \frac{4{,}000}{516.4} \times \$100 = \$1{,}549$$

   Step 2: Now, at the new setup cost, calculate the new optimal production quantity:

Practice

$Q = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-d}} = \sqrt{\frac{2(4{,}000)(25)}{5}}\sqrt{\frac{50}{50-20}} = 258.2\ tons$

Step 3: Calculate the new maximum inventory:

$I_{MAX} = \frac{Q}{p}(p-d) = \frac{258.2}{50}(50-20) = 154.92\ tons$

Step 4: Calculate the new total cost:

$Total\ cost = \frac{I_{MAX}}{2} \times H + \frac{D}{Q} \times S = \frac{154.92}{2} \times \$5 + \frac{4{,}000}{258.2} \times \$25 = \$774.5$

Step 5: Calculate the different between the total costs:

$Difference = \$1{,}549 - \$774.5 = \$774.5$

The company can save $\$774.5$ by reducing the setup cost to $\$25$.

5) Explain briefly how a higher carrying cost can result in a decrease in inventory.

As holding inventory becomes more expensive, the company will order in smaller quantities (note H in the formula for EOQ). This will result in more frequent orders.

6) Explain how a decrease in setup time can lead to a decrease in the average amount of inventory a firm holds, and why that would be beneficial.

As machine setup time decreases, setup cost decreases, resulting in lower run size (note S in the EPQ), which results in lower average amount of WIP inventory. Overall inventory costs would decrease. Also, lower WIP results in less confusion and better quality.

7. When does the total cost curve reach its minimum value?

When $Ordering\ costs = Carrying\ costs$.

Practice

TUTORIAL 7: INVENTORY MANAGEMENT II

1. A manufacturer of exercise equipment purchases pulleys from a supplier who lists these prices: less than 1,000, $5 each; 1,000 to 3,999, $4.95 each; 4,000 to 5,999, $4.90 each; and 6,000 or more, $4.85 each. Ordering cost is $50 per order, annual holding cost is 20% of purchase cost, and annual usage is 4,900 pulleys. Determine the order quantity that will minimize total cost.

$$D = 4{,}900\ pulleys/year,\ H = 0.20R,\ S = \$50$$

Range	**R**
$0 - 999$	$\$5.00$
$1{,}000 - 3{,}999$	$\$4.95$
$4{,}000 - 5{,}999$	$\$4.90$
$6{,}000 +$	$\$4.85$

$EOQ_{R=\$4.85} = \sqrt{\frac{2DS}{iR}} = \sqrt{\frac{2(4{,}900)(50)}{0.20(4.85)}} = 710.7$ or 711 pulleys. $711 < 6{,}000$, EOQ is not feasible.

$EOQ_{R=\$4.90} = \sqrt{\frac{2(4{,}900)(50)}{0.20(4.90)}} = 707.1$ or 707 pulleys. $707 < 4{,}000$, EOQ is not feasible.

$EOQ_{R=\$4.95} = \sqrt{\frac{2(4{,}900)(50)}{0.20(4.95)}} = 703.53$ or 704 pulleys. $704 < 1{,}000$, EOQ is not feasible.

$EOQ_{R=\$5.00} = \sqrt{\frac{2(4{,}900)(50)}{0.20(5.00)}} = 700$ pulleys. $0 \leq 700 < 999$, EOQ is feasible. Next, need to compare total cost of $Q = 700$ units with those of $Q = 1{,}000$, $Q = 4{,}000$, $Q = 6{,}000$.

$$TC_{700} = \frac{Q}{2}H + \frac{D}{Q}S + RD = \frac{700}{2}(0.20)(5.00) + \frac{4{,}900}{700}(50) + 5.00(4{,}900) = \$25{,}200$$

$$TC_{1{,}000} = \frac{1{,}000}{2}(0.20)(4.95) + \frac{4{,}900}{1{,}000}(50) + 4.95(4{,}900) = \$24{,}995$$

$$TC_{4{,}000} = \frac{4{,}000}{2}(0.20)(4.90) + \frac{4{,}900}{4{,}000}(50) + 4.90(4{,}900) = \$26{,}031.25$$

$$TC_{6{,}000} = \frac{6{,}000}{2}(0.20)(4.85) + \frac{4{,}900}{6{,}000}(50) + 4.85(4{,}900) = \$26{,}715.83$$

Therefore, the order quantity that will minimize total cost is $1{,}000$.

Practice

2. Demand for an item is projected to be 100 units per month. The monthly holding cost is $2 per unit, and it costs $55 to process an order.

a. Determine the EOQ.
b. If the demand can wait at the cost of $5 per unit per month, what should the order quantity and the amount short per order cycle be?

$$D = 100\ units/month,\ H = \$2/unit/month,\ S = \$55$$

a. $EOQ = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(100)(55)}{2}} = 74.16$ round to 74 units

b. $B = \$5/unit/month$

$Q = \sqrt{\frac{2DS}{H} \times \frac{H+B}{B}} = \sqrt{\frac{2(100)(55)}{2} \times \frac{2+5}{5}} = 87.75$ round to 88 units

$Q_b = Q \times \frac{H}{H+B} = 88 \times \frac{2}{2+5} = 25.1$ round to 25

Practice

3. A supermarket is open 360 days per year. Daily use of cash register tape averages 10 rolls, normally distributed, with a standard deviation of two rolls per day. The cost of ordering tapes is $10 per order, and holding cost is 40 cents per roll a year. Lead time is three days.

a. What is the EOQ?

b. What ROP will provide a lead time service level of 96 percent?

c. What ROP will provide an annual service level (i.e., fill rate) of 96 percent if order quantity = EOQ is used?

$360\ days,\ \overline{d} = 10\ rolls/day,\ \sigma_d = 2\ rolls/day,\ S = \$10,\ H = \$0.40/roll/year,\ LT = 3$

a. $D = \overline{d} \times number\ of\ days = 10\ rolls/day \times 360\ days/year = 3{,}600\ rolls/year$

$EOQ = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(3{,}600)(10)}{0.40}} = 424.3$ round to 424 rolls

b. Lead time SL of 96% → $z = 1.75$ from Table 12-3

$ROP = \overline{d} \cdot LT + z\sqrt{LT} \cdot \sigma_d = 10(3) + 1.75\sqrt{3}(2) = 36.06$ round to 36

c. $SL_{annual} = 96\% = 0.96$

$\sigma_{dLT} = \sigma_d\sqrt{LT} = 2\sqrt{3} = 3.46$

$E(z) = \frac{Q(1-SL_{annual})}{\sigma_{dLT}} = \frac{424(1-0.96)}{3.46} = 4.90$

$\Longrightarrow$ Table 12-3 to get z, but $E(z) = 4.90$ is not in the table.

However, note that for values of $E(z) > 2.4$, $z = -E(z)$.

Therefore, for $E(z) = 4.90$, $z = -4.90$.

$ROP = \overline{d} \cdot LT + z\sigma_{dLT} = 10(3) - 4.90(3.46) = 13.05$ round to 13

Practice

4. Demand for vanilla ice cream at a small ice cream shop can be approximated by a Normal Distribution with a mean of 21 litres per week and a standard deviation of 3.5 litres per week. The ice cream is purchased from an ice cream producer. The store manager desires a lead time service level of 90 percent. Lead time from the producer is two days. The store is open seven days a week.

a. If the EOQ/ROP model is used for ordering the ice cream from the producer, what ROP would be consistent with the desired lead time service level?

b. If a fixed interval model is used instead, what order quantity should be used if the order interval is 7days and 8 litres are in hand and none are on order at the time of order?

$$\bar{d} = 21\ litres/wk,\ \sigma_d = 3.5\ litres/wk,\ SL = 90\%,\ LT_{days} = 2\ days,\ open\ 7\ days/wk$$

a. $SL = 0.9 \rightarrow z = 1.28$ from Table 12-3

$$LT_{weeks} = \frac{LT_{days}}{number\ of\ days/week} = \frac{2\ days}{7\ days/week} = \frac{2}{7}\ weeks$$

$$ROP = \bar{d} \cdot LT + z\sqrt{LT} \cdot \sigma_d = 21\left(\frac{2}{7}\right) + 1.28\sqrt{\frac{2}{7}}(3.5) = 8.39\ litres$$

b. $OI_{days} = 7\ days,\ on\ hand\ (inventory\ position) = 8\ litres,\ I_{max}: order\ up\ to\ level$

$$OI_{weeks} = \frac{OI_{days}}{number\ of\ days} = \frac{7\ days}{7\ days/week} = \frac{7}{7}\ weeks$$

$$I_{max} = \bar{d}(OI + LT) + z \cdot \sigma_d\sqrt{OI + LT} = 21\left(\frac{7}{7} + \frac{2}{7}\right) + 1.28(3.5)\sqrt{\frac{7}{7} + \frac{2}{7}} = 32.08$$ round to 32 litres

$$Q(order\ quantity) = I_{max} - on\ hand = 32 - 8 = 24\ litres$$