Practice

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

$F_1 = 20$

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

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

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

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

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

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

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

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

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

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

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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:

P3-11
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		

	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 ΣAvg_s
avg	0.789	1.341	0.868	2.997
adjusted	0.790	1.342	0.868	3.000

SR

Adjusted SRs

$CMA_3 \rightarrow$ 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

$$\text{Adjusted SR} = Avg_s \times \frac{\text{No. of seasons}}{\Sigma Avg}$$

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

$$= 0.790$$

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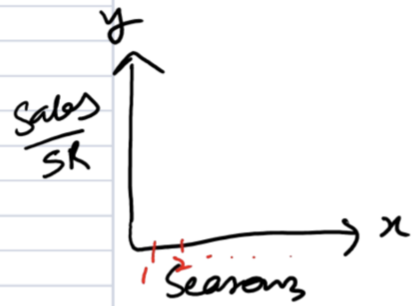
Practice

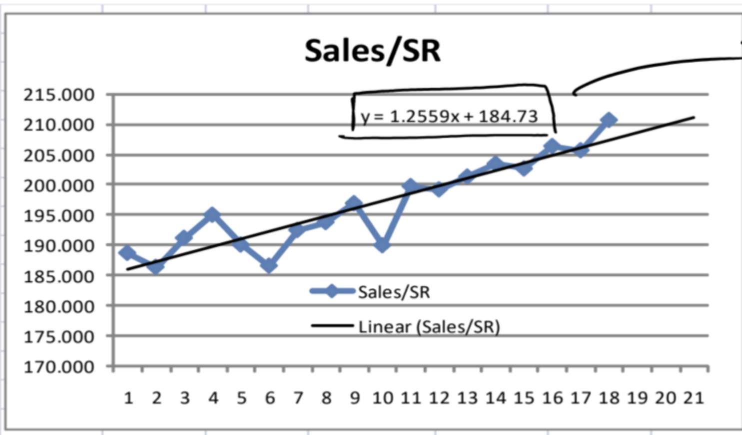
b) Deseasonalized data is shown as the values in the $Sales/SR$ column:

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:



$x = 19$

$y = 1.2559(19) + 184.73$

$= 208.592$

Final Step:

* Reseasonalize the trend forecasted values from model.

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

* Reseasonalizing = TF value × SR

$= 208.592 \times 0.790$

$= 164.740$

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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.

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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. $average\ price = \$3.00, average\ cost = \$1.00, fixed\ cost = \$260{,}000$

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

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

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

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

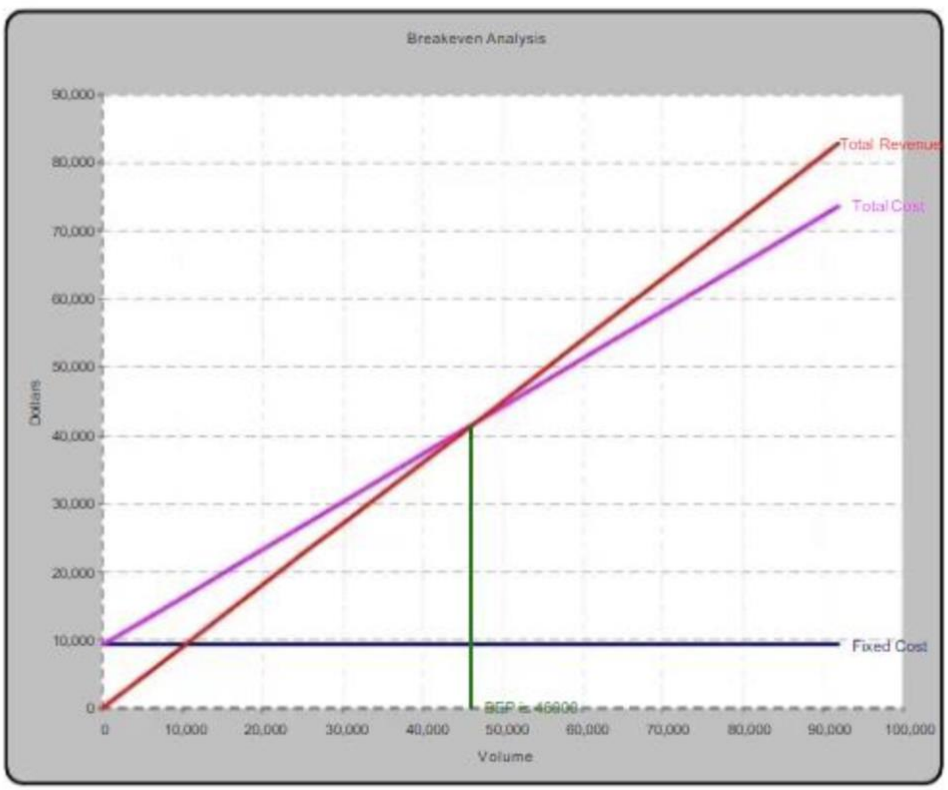
$$P_1 = 61{,}000(0.9-0.7) - 9{,}200 = \$3{,}000$$

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

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:



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

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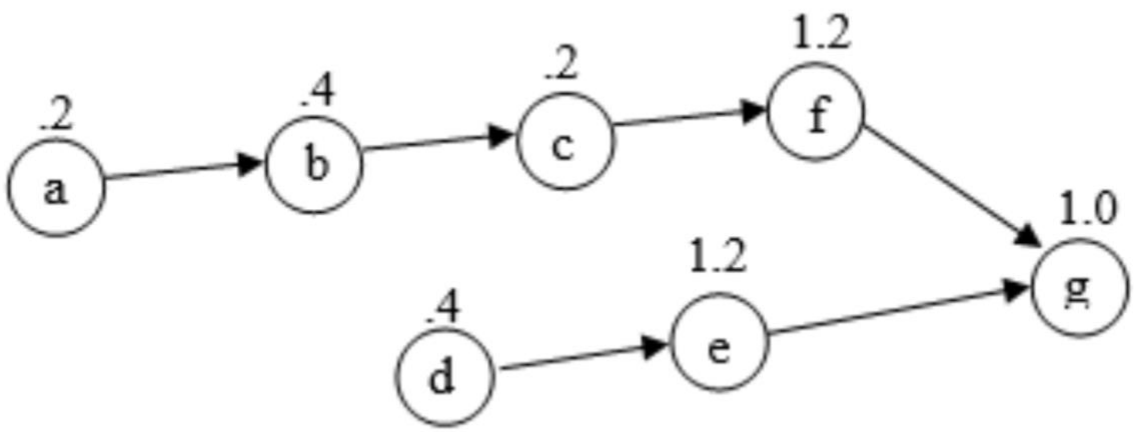
Practice

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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Practice

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

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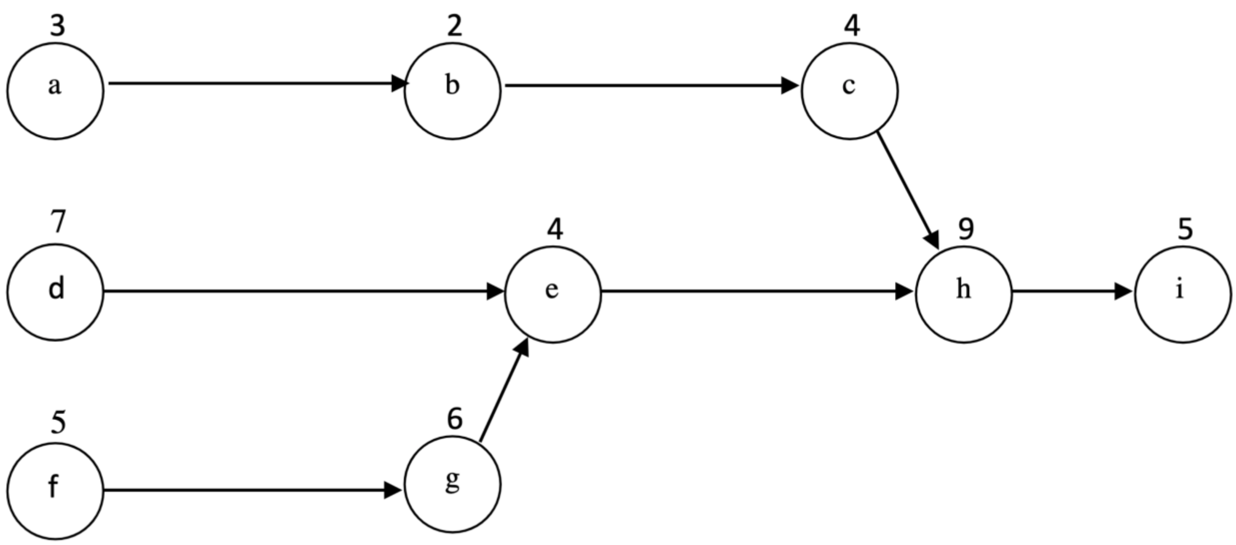
Practice

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:

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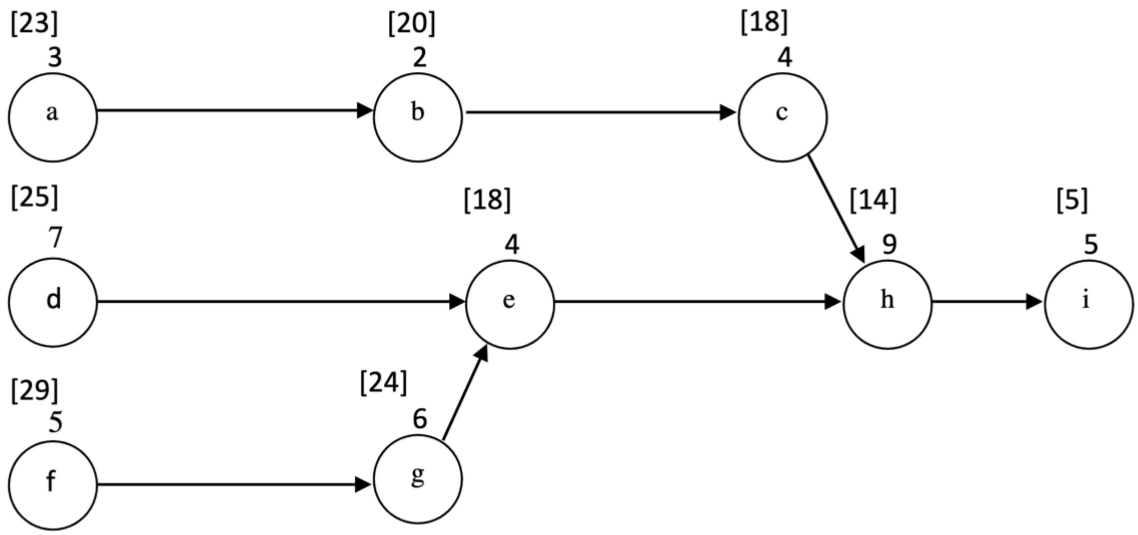
Practice



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.

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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:

<u>Problem Type</u>

N: Noisy

F: Equipment Failure

W: Runs warm

O: Odour

<u>Customer Type</u>

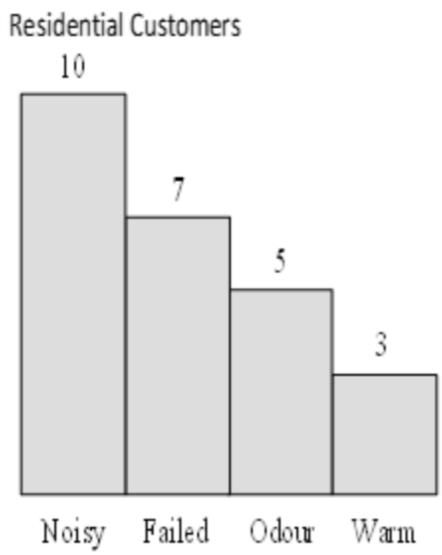
C: Commercial customer

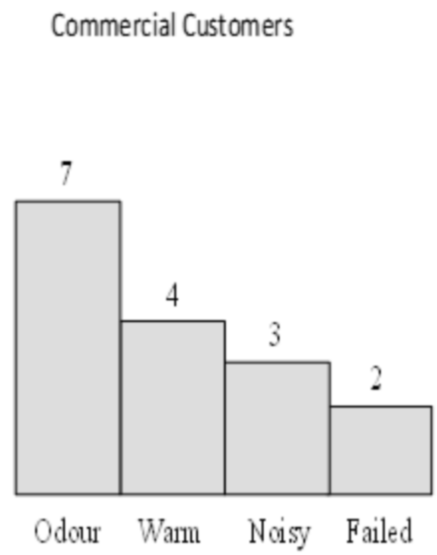
R: Residential customer

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*





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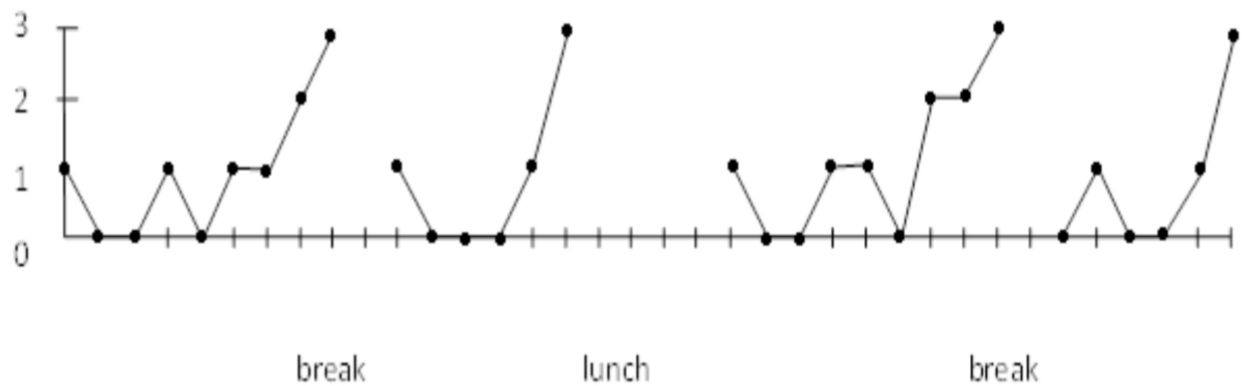
Practice

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?

MSCI 432 Winter 2020 – Production and Service Operations Management

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.

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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.

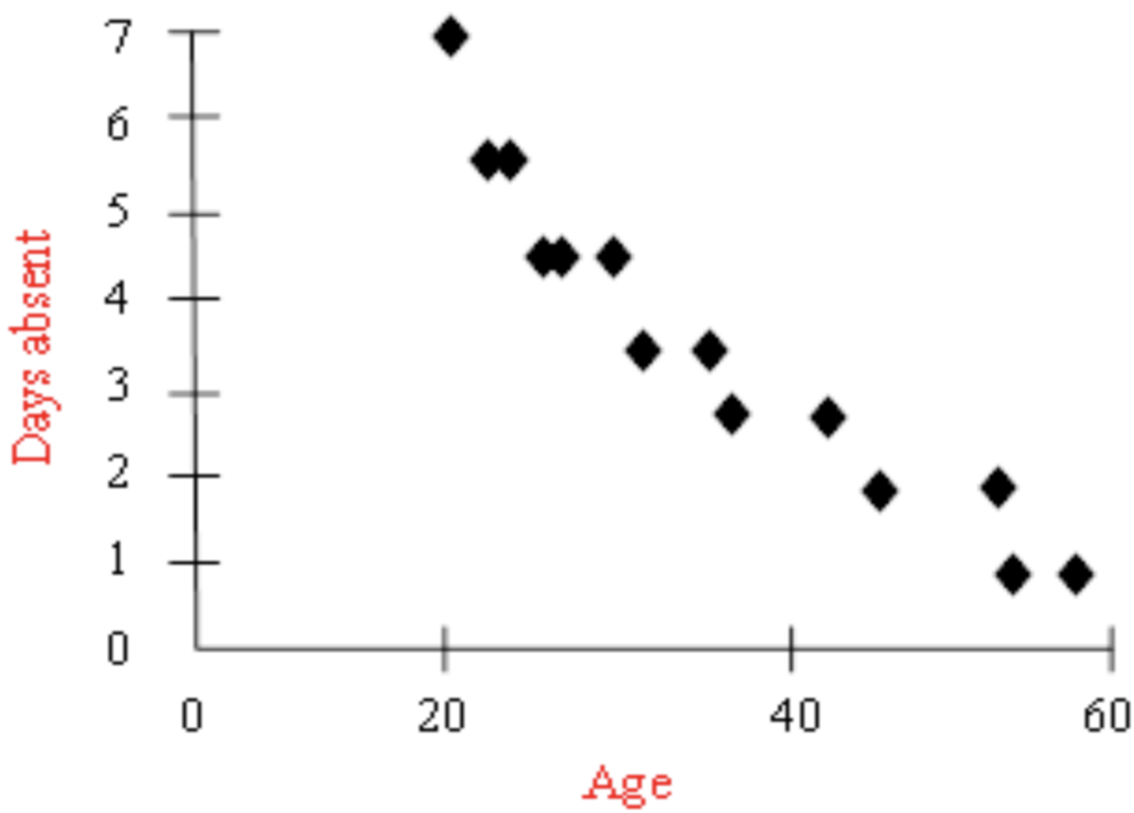
a.

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.

b. Scatter diagram for b:

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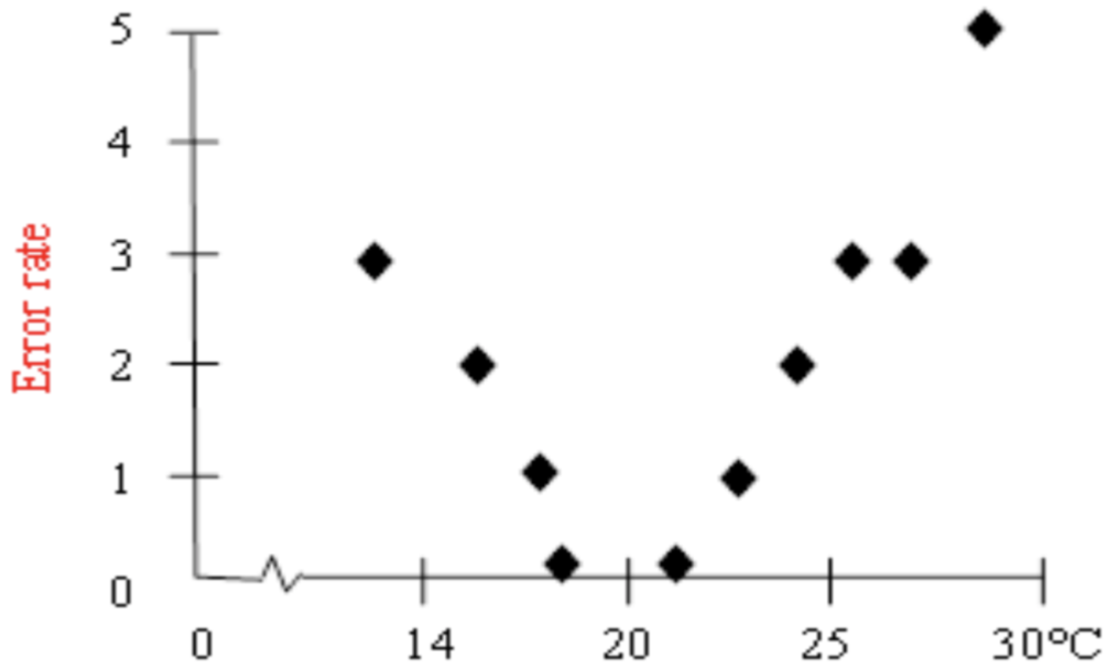

Error rate is non-linearly related to temperature. It increases in colder or hotter temperatures. The lowest error rate occurs around $20°C$.

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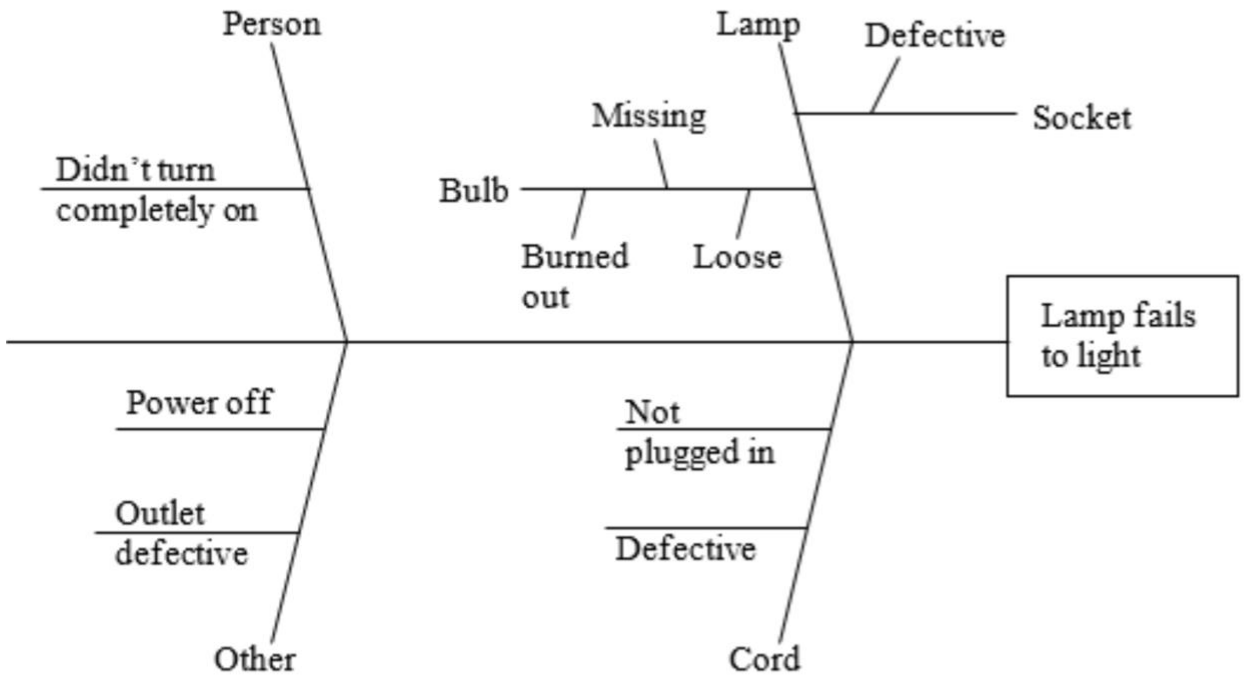
Practice

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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Practice

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

$$For\ n = 5, from\ Table\ 10-3: A_2 = 0.58, D_3 = 0, D_4 = 2.11$$

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.

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