SOLUTIONS

ASSIGNMENT # 1
FORECASTING and AGREGATE PLANNING

TOTAL: 145 points

General marking rules

Penalty for submission after the deadline.

10% deduction for less than 24 hours. However, those who submitted by 6:00 a.m. don't penalize.

20 % deduction for 1 day late

40 % deduction for 2 days late

60% deduction for 3 days late

80% deduction for 4 days late

100% deduction for 5 days late.

If the statement of integrity is not available or not signed by a given student, deduct 10 points.

Do not penalize twice for an error that occurs at the start and it does affect the results that follows.

Students: Please note that the solutions for Assignment 2 will not be posted.

Problem 1 – Jackson Manufacturing Corporation (30 points)

a) Since the sales level is shifting significantly from month to month, and there is no consistent trend, the naive method seems like it will perform well (if they mention multiplicative decomposition model, accept as well) **(1 point).**

The moving-average method will will lag any short-term trends. The exponential smoothing method will also lag trends. **(1 point)**

Exponential smoothing with trend will likely not do well because the trend is not consistent. **(1 point).**

b) **(6 points). Deduct 2 points per mistake.**

naive method:

	A	B	C	D	E	F	G	H	I
3	Time	True	Naïve		Forecasting				
4	Period	Value	Forecast		Absolute Error		Error^2	Mean Absolute Deviation	
5	1	126						MAD =	5.3
6	2	137	126		11		121		
7	3	142	137		5		25	Mean Square Error	
8	4	150	142		8		64	MSE =	36.2
9	5	153	150		3		9		
10	6	154	153		1		1		
11	7	148	154		6		36		
12	8	145	148		3		9		
13	9	147	145		2		4		
14	10	151	147		4		16		
15	11	159	151		8		64		
16	12	166	159		7		49		
17	13		166	MAD	=AVERAGE(E6:E16)	MSE	=AVERAGE(G6:G16)		

moving average (n=4):

Time Period	True Value	Average Forecast	Forecasting Error		Number of previous periods to consider	
1	126				n=	4
2	137					
3	142				Mean Absolute Deviation	
4	150				MAD =	7.9
5	153	139	14			
6	154	146	9		Mean Square Error	
7	148	150	2		MSE =	87.4
8	145	151	6			
9	147	150	3			
10	151	149	3			
11	159	148	11			
12	166	151	16			
13		156				

Comparing MAD values (5.3, and 7.9, respectively), the naive method is the best to use.
Comparing MSE values (36.2, and 87.4, respectively), the naive-value method is the best to use.

c) **(6 points). Deduct 2 points per mistake.**
Refer to the Excel spreadsheet for calculations.

Using the template for exponential smoothing, with an initial estimate of 120, the following forecast errors were obtained for various values of the smoothing constant α:

Smoothing Constant	MAD	MSE
0.1	18.5	382.7
0.3	10.1	139.7
0.5	8.0	82.9

Considering both MAD and MSE, it appears that a high value for the smoothing constant is appropriate.

<u>Sample Excel spreadsheet for alpha = 0.1:</u>

Time Period	True Value	Exp. Smoothing Forecast	Forecasting Abs. Error	Err^2		
					Smoothing Constant	
1	126	120.000000	6	36	α =	0.1
2	137	120.600000	16	269		
3	142	122.240000	20	390	**Initial Estimate**	
4	150	124.216000	26	665	Average =	120
5	153	126.794400	26	687		
6	154	129.414960	25	604	**Mean Absolute Deviation**	
7	148	131.873464	16	260	MAD =	18.5
8	145	133.486118	12	133		
9	147	134.637506	12	153	**Mean Square Error**	
10	151	135.873755	15	229	MSE =	382.7
11	159	137.386380	22	467		
12	166	139.547742	26	700		
13	-	142.192968	-	-	(This row is NOT included in MSE/MAD calculation)	

d) **(6 points). Deduct 2 points per mistake.** Refer to the Excel spreadsheet for calculations.

Using the template for exponential smoothing with trend, using initial estimates of 120 for the average value and 10 for the trend, the following forecast errors were obtained for various values of the smoothing constants α and β:

α	β	MAD	MSE
0.3	0.3	9.8	144.1
0.3	0.5	8.8	111.5
0.5	0.3	7.0	72.2
0.5	0.5	6.5	61.1

Considering both MAD and MSE, it appears that a high value for both smoothing constants is appropriate.

Sample Excel spreadsheet for alpha = 0.5, beta = 0.5:

				Double Exponential				
Time	True			Smoothing	Forecasting			
Period	Value	Ft	Tt	Forecast	Absolute Error		Smoothing Constants	
1	126	120.00	10.00	130.000000	4		α =	0.5
2	137	128.00	9.00	137.000000	0		β =	0.5
3	142	137.00	9.00	146.000000	4			
4	150	144.00	8.00	152.000000	2		Initial Estimates	
5	153	151.00	7.50	158.500000	6		Average =	120
6	154	155.75	6.13	161.875000	8		Trend =	10
7	148	157.94	4.16	162.093750	14			
8	145	155.05	0.63	155.679688	11		Mean Absolute Deviation	
9	147	150.34	-2.04	148.302734	1		MAD =	6.5
10	151	147.65	-2.36	145.288574	6			
11	159	148.14	-0.93	147.209351	12		Mean Square Error	
12	166	153.10	2.01	155.117401	11		MSE =	61.1
13	-	160.56	4.73	165.292076	-			

e) **(3 points): allocate full grade for either one of the answer below.**
Management should use the naive method to forecast sales (1 point). Using this method, the forecast for January of the new year will be 166 million dollars (i.e. $166,000,000). (2 points)
OR
Exponential smoothing with trend adjustement (double exponential smoothing) with high smoothing constants (e.g., □ = 0.5 and □ = 0.5) also works well (1 point). With this method, the forecast for January of the new year will be $165,292,076. (2 points).

f) **(3 points): The gist of this question is to break down the sales and use different frocasting method for the stable versus the new products. Use your own judgment to allocate partial marks or full marks.**

Forecasting might be improved by breaking down total sales into stable and new products. Exponential smoothing with a relatively small smoothing constant can be used for the stable product base. Exponential smoothing with trend, with a relatively large smoothing constant, can be used for forecasting sales of each new product.

g) **(3 points): Use your own judgment to allocate partial marks or full marks.**

Managerial judgment is needed to provide the initial estimate of anticipated sales in the first month for new products. In addition, a manger should check the exponential smoothing forecasts and make any adjustments that may be necessary based on knowledge of the marketplace.

Problem 2 – Better Health Inc. (22 points)

a)

(14 marks): If they don't provide detail calculations and everything is correct then deduct 7 marks.

- 8 marks for the correct adjusted seasonal indices.

Deduct 2 marks for each different type of mistake that shows in the calculation of the seasonal indices. Thus the student would get either 0 (For four different types of mistakes) or 2 (for three different mistakes)… or 6 (for one mistake) or the full grade.

- 4 marks for Trend estimation **(on the de-seasonalized demand or centered moving average).**
- 2 marks: for answering the question:" Better Health Inc. is wondering if it should expand in all four seasons or if it should concentrate on one. The company would like to know if the growth has been even in all four seasons or not." : No need to expand to all four seasons. Spring demand for the program is below the average yearly demand. The most popular is Winter, followed by the fall this can be the focus of the expansion.

If students regressed deseasonalized demand, then students would have the following results:

Seasonal Indices	
1	1.049
2	0.898
3	1.036
4	1.017
Intercept	52.2809
Slope	1.2347

If students regressed CMA, then students would have the following results:

Seasonal Indices	
1	1.049
2	0.898
3	1.036
4	1.017
Intercept	54.2036
Slope	1.2004

						SUM of Season Indices				
Input Data			**Seasonal Index Computation**			4.010	4.000			
Period	At	t	moving average MA(4)	CMA	St x Rt	Seasonal index	Adjusted Seasonal indices = St	Deseasonalized demand	Tt	Ft
Quarter 1	35	1				1.052	1.049	33.366	53.516	56.137
Quarter 2	44	2	45.5			0.900	0.898	49.002	54.750	49.161
Quarter 3	54	3	53.75	49.625	1.088	1.039	1.036	52.125	55.985	57.999
Quarter 4	49	4	58	55.875	0.877	1.020	1.017	48.175	57.220	58.200
Quarter 5	68	5	59.75	58.875	1.155	1.052	1.049	64.825	58.454	61.317
Quarter 6	61	6	66.25	63.000	0.968	0.900	0.898	67.935	59.689	53.596
Quarter 7	61	7	66.75	66.500	0.917	1.039	1.036	58.882	60.924	63.115
Quarter 8	75	8	67	66.875	1.121	1.020	1.017	73.737	62.158	63.223
Quarter 9	70	9	69.25	68.125	1.028	1.052	1.049	66.732	63.393	66.498
Quarter 10	62	10	69	69.125	0.897	0.900	0.898	69.049	64.628	58.030
Quarter 11	70	11	67.5	68.250	1.026	1.039	1.036	67.569	65.862	68.232
Quarter 12	74	12	70	68.750	1.076	1.020	1.017	72.754	67.097	68.246
Quarter 13	64	13	71.5	70.750	0.905	1.052	1.049	61.012	68.332	71.678
Quarter 14	72	14	71	71.250	1.011	0.900	0.898	80.186	69.566	62.465
Quarter 15	76	15	73.25	72.125	1.054	1.039	1.036	73.361	70.801	73.348
Quarter 16	72	16	70.75	72.000	1.000	1.020	1.017	70.787	72.036	73.270
Quarter 17	73	17	73	71.875	1.016	1.052	1.049	69.592	73.270	76.859
Quarter 18	62	18	73	73.000	0.849	0.900	0.898	69.049	74.505	66.899
Quarter 19	85	19	77	75.000	1.133	1.039	1.036	82.048	75.740	78.464
Quarter 20	72	20	78	77.500	0.929	1.020	1.017	70.787	76.974	78.293
Quarter 21	89	21	77.25	77.625	1.147	1.052	1.049	84.845	78.209	82.039
Quarter 22	66	22	82.25	79.750	0.828	0.900	0.898	73.503	79.444	71.334
Quarter 23	82	23	84	83.125	0.986	1.039	1.036	79.152	80.678	83.581
Quarter 24	92	24	87	85.500	1.076	1.020	1.017	90.451	81.913	83.316
Quarter 25	96	25	90.25	88.625	1.083	1.052	1.049	91.518	83.148	87.220
Quarter 26	78	26	90.75	90.500	0.862	0.900	0.898	86.868	84.382	75.768
Quarter 27	95	27	90	90.375	1.051	1.039	1.036	91.701	85.617	88.697
Quarter 28	94	28	90	90.000	1.044	1.020	1.017	92.417	86.852	88.339
Quarter 29	93	29	90	90.000	1.033	1.052	1.049	88.658	88.086	92.400
Quarter 30	78	30	90	90.000	0.867	0.900	0.898	86.868	89.321	80.203
Quarter 31	95	31	90.5	90.250	1.053	1.039	1.036	91.701	90.556	93.813
Quarter 32	94	32	91.5	91.000	1.033	1.020	1.017	92.417	91.790	93.363
Quarter 33	95	33	90	90.750	1.047	1.052	1.049	90.565	93.025	97.581
Quarter 34	82	34	88.25	89.125	0.920	0.900	0.898	91.322	94.259	84.637
Quarter 35	89	35				1.039	1.036	85.909	95.494	98.930
Quarter 36	87	36				1.020	1.017	85.535	96.729	98.386
						Intercept		**52.2809**		
						Slope		**1.2347**		

SUMMARY OUTPUT DESEASONALIZED DATA

Regression Statistics	
Multiple R	0.88246084
R Square	0.77873714
Adjusted R Square	0.77222941
Standard Error	7.0349903
Observations	36

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	5922.271	5922.271	119.6634	1.12E-12
Residual	34	1682.697	49.49109		
Total	35	7604.968			

	Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Ipper 95.0%*
Intercept	52.2809378	2.39472	21.83176	1.39E-21	47.41428	57.14759	47.41428	57.14759
X Variable 1	1.23466357	0.112867	10.93908	1.12E-12	1.00529	1.464037	1.00529	1.464037

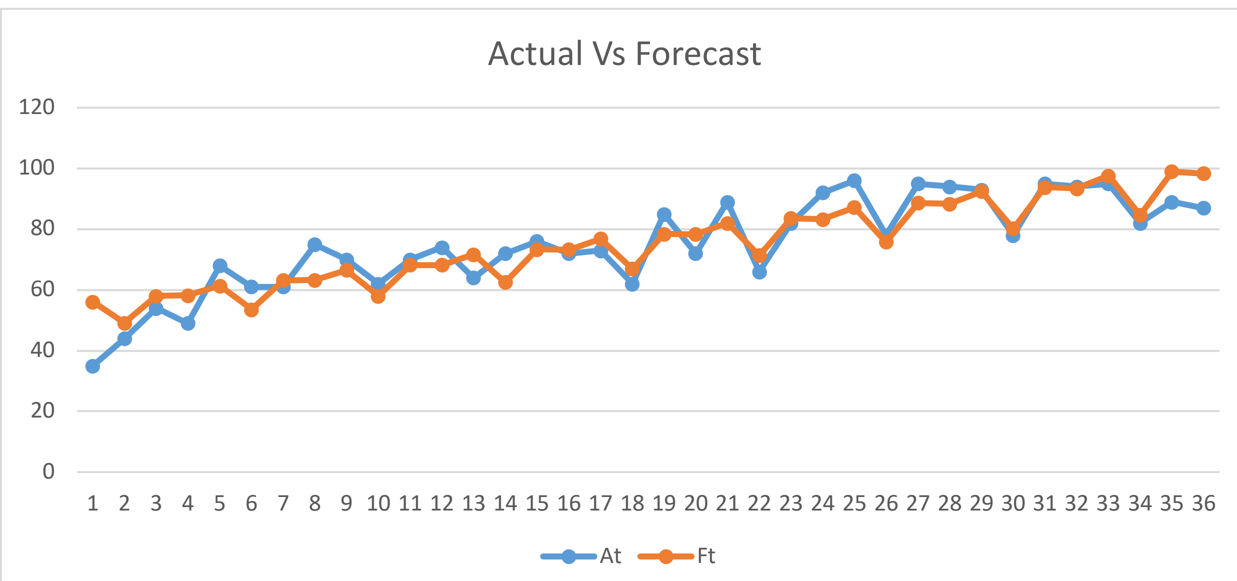
SUMMARY OUTPUT CMA DATA								
Regression Statistics								
Multiple R	0.967025913							
R Square	0.935139116							
Adjusted R Square	0.932977087							
Standard Error	3.014559031							
Observations	32							
ANOVA								
	df	*SS*	*MS*	*F*	*ignificance F*			
Regression	1	3930.63	3930.63	432.5284	2.25E-19			
Residual	30	272.627	9.087566					
Total	31	4203.257						
	Coefficients	*tandard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Ipper 95.0%*
Intercept	54.20362903	1.193355	45.42121	3.22E-29	51.76647	56.64079	51.76647	56.64079
X Variable 1	1.200352823	0.057717	20.79732	2.25E-19	1.08248	1.318226	1.08248	1.318226

b) (4 marks): Two options to justify that kind lead to similar conclusions.

First option:

We have time-series data for 36 quarters and there are 4 seasons each year. The resulting measure of accuracy (i.e. Sigma --- or MAPE is 8.58%). The graph indicates that while the forecasting model does a good job overall of replicating the pattern of participant values, there are sizable differences in some quarters (Check the plot of the Forecast Vs Actual below) **(2 marks)**

The relatively large errors in the last two quarters are particularly disturbing and could indicate, for example, some recent occurrence (such as a new competitor) that is obviously not being detected by the model. **(2 marks)**.

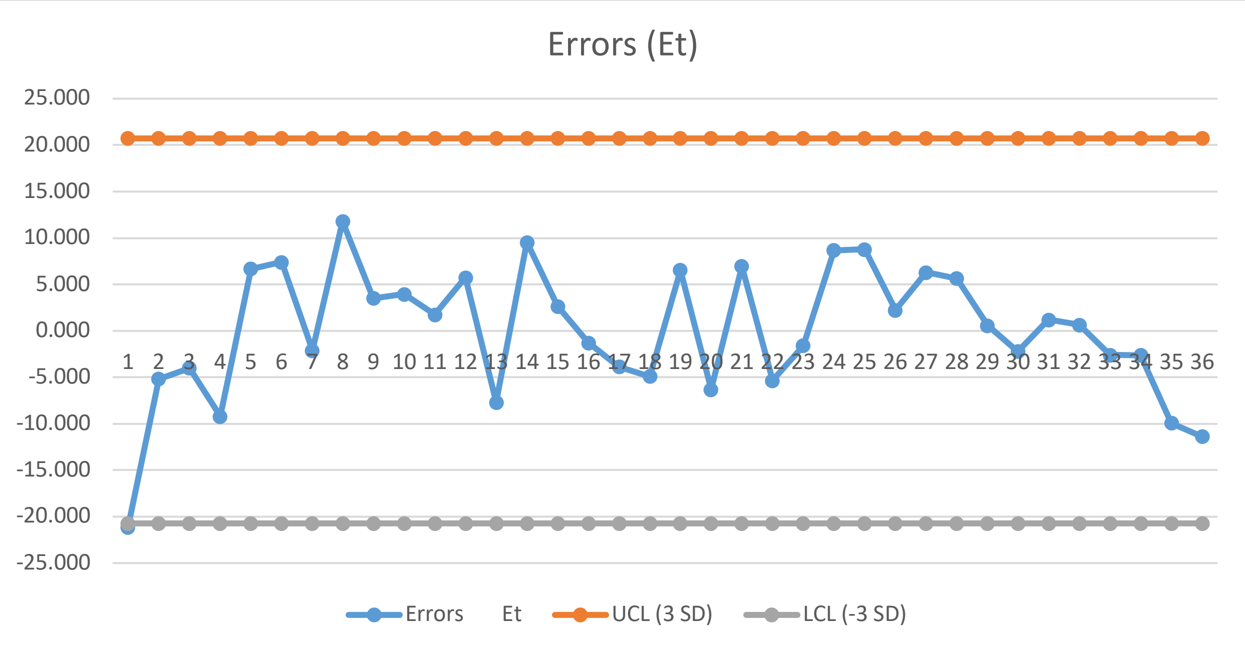


Second option:

The coefficient of determination and correlation when using linear regression to forecast trend indicate that linear regression is a moderate predictor of the trend components (on the deasonalized demand). The t-stat > 2 and p value < 0.05. **(1 mark).**

However, when we plot the Errors. The errors are not randomly distributed around the mean zero (most error terms are positive). The method should be investigated and reasons for errors in the last two quarters. **(3 marks).**

If students constructed a control chart with 3 sigma, the initial error term is not within the lower bound. However, the error terms adjust within the UCL and LCL but remain mostly positive. Students can estimate the Tt on the CMA column and see if result improve.



c) (4 marks)

Take off **(2 marks)** if the forecast for period 37 to 40 were **not rounded** to INTEGER value. The Forecast for Period 37 to 40 is the **number of programs to offer. Thus, it needs to be an integer value (either rounding to the nearest integer or rounding up would work)**

Time DECOMPOSITION Model on de-seasonalized demand.

Period	Tt	St	Forecast for 2019
37.000	97.963	1.049	**103**
38.000	99.198	0.898	**89**
39.000	100.433	1.036	**104**
40.000	101.667	1.017	**103**

Time DECOMPOSITION Model on de-seasonalized demand on CMA

Period	Tt	St	Forecaset for 2019
37.000	98.617	1.049	**103**
38.000	99.817	0.898	**90**
39.000	101.017	1.036	**105**
40.000	102.218	1.017	**104**

Problem 3 – Riverside zoo (18 points)

a)15 points

3 points building time series model (i.e. Linear regression with time as the independent variable)

2 points for the forecast of the next 2 years using time series

4 points building the casual model (i.e. Linear regression with weighted average admission fees as the independent variables)

2 points for the forecast of the next 2 years using casual model

4 points for comparing the 2 models based on Errors and R-squared. Please note that in Section M and N, I don't base the comparison on MAPE thus if they use other measure of accuracy (MSE, MAD) to conclude consider it as correct.

The idea is that attendance is a linear function of expected admission fees.

First, we perform a linear regression with time as the independent variable. The model is shown in file "Problem 3.xlsx", sheet problem 3 a) #1. The regression equation is:

Average admissions = 44,352.4 + 9197.3 × year

where 2006 = year 1, 2007 = year 2, and so on. R2 = 77.6%. MAPE = 9.94%. The forecasts for 2017 (year 11) and 2018 (year 12) are 145,523 and 154,720, respectively. Using a weighted average of $2.875 to represent gate receipts per person, revenues for 2019 and 2020 are $418,378 and $444,820, respectively.

Riverside Zoo (#1)

TimeSeries regression analysis

Input Data				Forecast Error Analysis				
Period	Dep Variable (or) (Y)	Indep Variable (or) (X)		Forecast	Error	Absolute error	Squared error	Absolute % error
2009	53353	1		53549.709	-196.709	196.709	38694.466	0.37%
2010	61417	2		62747.018	-1330.018	1330.018	1768948.364	2.17%
2011	63853	3		71944.327	-8091.327	8091.327	65469577.034	12.67%
2012	63034	4		81141.636	-18107.636	18107.636	327886494.678	28.73%
2013	95504	5		90338.945	5165.055	5165.055	26677788.458	5.41%
2014	133762	6		99536.255	34225.745	34225.745	1171401651.919	25.59%
2015	108363	7		108733.564	-370.564	370.564	137317.409	0.34%
2016	126853	8		117930.873	8922.127	8922.127	79604355.071	7.03%
2017	125363	9		127128.182	-1765.182	1765.182	3115866.851	1.41%
2018	117874	10		136325.491	-18451.491	18451.491	340457516.768	15.65%
				Average		**9662.585**	**201655821.102**	**9.94%**
Intercept	**44352.400**					**MAD**	**MSE**	**MAPE**
Slope	**9197.309**							
				Sigma	**15876.705**	or	14200.557	
Forecast	**145522.800**	11		**Correlation**	**0.881**		=SQRT(H17)	
	154720.109	12		**r-squared**	**0.776**			

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.880806595							
R Square	0.775820257							
Adjusted R Square	0.74779779							
Standard Error	15876.70546							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	1	6978715797	6.98E+09	27.68565	0.000763			
Residual	8	2016558211	2.52E+08					
Total	9	8995274008						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Jpper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	44352.4	10845.85461	4.089341	0.003489	19341.81	69362.99	19341.81	69362.99
X Variable 1	9197.309091	1747.967742	5.261716	0.000763	5166.488	13228.13	5166.488	13228.13

Here is an alternate linear regression model that uses the weighted average admission fees as the independent variable (X). Weights are obtained each year by taking 35% of adult fees, plus 50% of children's fees, plus 15% of group fees. The weighted fees each year (2009–2019) are \$0.975, \$0.975, \$0.975, \$0.975, \$1.275, \$1.775, \$1.775, \$2.275, \$2.20, and \$2.875 respectively. The model is shown in file "Problem 3.xlsx", sheet problem 3 b) #2. The regression equation is:

Average gate admissions = 31,598.4 + 39,402.3 × (Average fee in given year)

R2 = 72%. MAPE = 14.36%. If we assume that admission fees are not raised in 2019 and 2020, expected gate admissions = 144,880 in each year, and revenues = \$416,530. Comparing the earlier time-series model to this second regression, we note that R2 is higher and MAPE is lower in the time-series approach.

Riverside Zoo (#2)

Causal regression analysis

Weighted Average

Input Data				Forecast Error Analysis				
Period	Dep Variable (or) (Y)	Indep Variable (or) (X)		Forecast	Error	Absolute error	Squared error	Absolute % error
2009	53353	0.975		70015.645	-16662.645	16662.645	277643739.872	31.23%
2010	61417	0.975		70015.645	-8598.645	8598.645	73936696.598	14.00%
2011	63853	0.975		70015.645	-6162.645	6162.645	37978193.942	9.65%
2012	63034	0.975		70015.645	-6981.645	6981.645	48743367.524	11.08%
2013	95504	1.275		81836.335	13667.665	13667.665	186805062.674	14.31%
2014	133762	1.775		101537.485	32224.515	32224.515	1038419347.362	24.09%
2015	108363	1.775		101537.485	6825.515	6825.515	46587650.859	6.30%
2016	126853	2.275		121238.635	5614.365	5614.365	31521089.108	4.43%
2017	125363	2.200		118283.463	7079.537	7079.537	50119844.946	5.65%
2018	117874	2.875		144880.016	-27006.016	27006.016	729324881.949	22.91%
				Average		**13082.319**	**252107987.483**	**14.36%**
Intercept	**31598.402**	31598.40223				**MAD**	**MSE**	**MAPE**
Slope	**39402.300**	39402.30033						
				SE	**17752.042**	or	15877.909	
Forecast	**144880.016**	2.875		**Correlation**	**0.848**		=SQRT(H17)	
				r-squared	**0.720**			

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.848370699							
R Square	0.719732843							
Adjusted R Square	0.684699448							
Standard Error	17752.0417							
Observations	10							
ANOVA								
	df	*SS*	*MS*	*F*	*gnificance F*			
Regression	1	6474194134	6.47E+09	20.54419	0.001918			
Residual	8	2521079875	3.15E+08					
Total	9	8995274008						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	31598.40223	15059.63851	2.098218	0.069129	-3129.19	66325.99	-3129.19	66325.99
X Variable 1	39402.30033	8693.147073	4.53257	0.001918	19355.87	59448.73	19355.87	59448.73

b) Other factors are the variability of the weather, the special events, the competition, and the role of advertising. **(3 points)**

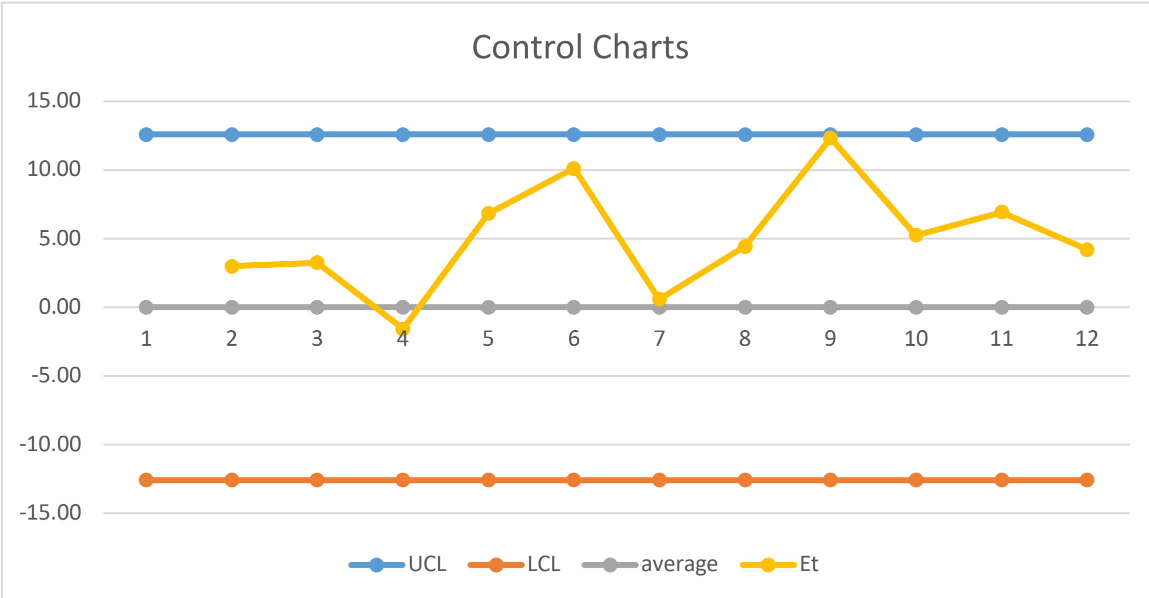
Problem # 4 (15 points)

a) Construct a Control Chart to monitor the forecast accuracy using control limits of ± 2σ (i.e. σ = standard deviation). Show your work. (10 points)

5 marks: for the correct Standard deviation, the Upper Control Limit and the Lower Control Limit. (deduct two marks for each mistake)

5 marks for the plot. (deduct two marks for each missing info/mistakes)

Period	**Month**	**Demand for Repair and Service Calls**	**Forecast**	**Et**	**Et^2**	
1	January	37	37.000			
2	February	40	37.000	3.000	9.000	
3	March	41	37.750	3.250	10.563	
4	April	37	38.563	-1.563	2.441	
5	May	45	38.172	6.828	46.623	
6	June	50	39.879	10.121	102.437	
7	July	43	42.409	0.591	0.349	
8	August	47	42.557	4.443	19.741	
9	September	56	43.668	12.332	152.087	
10	October	52	46.751	5.249	27.555	
11	November	55	48.063	6.937	48.121	
12	December	54	49.797	4.203	17.663	
				5.036	39.689	6.299921
				ME=	MSE=	Sigma
Z=	2					
UCL=	12.5998427					
LCL=	-12.599843					



b) Is the forecast performing adequately? Explain. (5 marks)

Although it could be observed that all the errors values are within the control limits, we can still detect that most of the errors are positive, indicating a low bias in the forecast estimates. Thus the errors are NOT randomly distributed around the mean/average Zero. This suggests that the forecast is not performing accurately (actual demand most of the time exceeds the forecast). Simple exponential smoothing with alpha = 0.25 is not a good model to use.

Problem 5: 60 points

a) 12 points (2 points per mistake)

- Please note in the chase strategy idle time is allowed (no building inventory beyond what is needed).
- number of workers INTEGER and rounded up (number of workers hired and fired) needed each month.

a) A Chase Strategy										
number of employees		5								
Units/employee		8								
Period		***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	TOTAL
Forecast			50	44	55	60	60	40	50	359
Reg. Prod.	40		50	44	55	60	60	40	50	359
Employee hired			2	0	1	1	0	0	2	6
Employee Fired			0	1	0	0	0	3	0	4
Final Inventory		0								
Reg. Cost	$240		$12,000	$10,560	$13,200	$14,400	$14,400	$9,600	$12,000	$86,160
Hired Cost	$500		$1,000	$0	$500	$500	$0	$0	$1,000	$3,000
Fire Cost	$1,000		$0	$1,000	$0	$0	$0	$3,000	$0	$4,000
TOTAL			$13,000	$11,560	$13,700	$14,900	$14,400	$12,600	$13,000	**$93,160**

In Chase Strategy:

- Regular production must be equal to forecast for each month.
- Overtime and Subcontracting is not allowed. Variation in regular production is controlled only by hiring and firing the employees.

b) 12 points

- 2 points per mistake, however if backorder cost is not carried through then deduct 4 points mark.

	A	B	C	D	E	F	G	H	I	J	K
1	b) A level strategy			=ROUND(D2-B6-B7,0)				=MAX(K5-K6-K7-((G2*6)),0)			
2	quantity to produce per month			52		then	4	units in subcontracting from March to April			
3							0	units in subcontracting in September			
4	Period		***0***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	TOTAL
5	***Forecast***			50	44	55	60	60	40	50	359
6	***Reg. Prod.***	40		40	40	40	40	40	40	40	280
7	***O.T. Prod.***	8		8	8	8	8	8	8	7	55
8	***subcontract***	12		4	4	4	4	4	4	0	24
9	***Final Inventory***		0	2	10	7	0	0	3	0	22
10	***Backorder***			0	0	0	1	9	0	0	10
11		=(8/5)*[Number of Employees=5]									
12	***Reg. Cost***	$240		$9,600	$9,600	$9,600	$9,600	$9,600	$9,600	$9,600	$67,200
13	***O.T Cost***	$360		$2,880	$2,880	$2,880	$2,880	$2,880	$2,880	$2,520	$19,800
14	***Sub. Cost***	$420		$1,680	$1,680	$1,680	$1,680	$1,680	$1,680	$0	$10,080
15	***Inv. Cost***	$50		$100	$500	$350	$0	$0	$150	$0	$1,100
16	***Backorder Co***	$100		$0	$0	$0	$100	$900	$0	$0	$1,000
17	TOTAL			$14,260	$14,660	$14,510	$14,260	$15,060	$14,310	$12,120	**$99,180**

* Note that [total production (including regular and overtime) + outsourced amount] must be equal to total forecast: (280 + 55) + 24 = 359

c) 10 points

- 6 points: for finding the production plan using a mixed strategy that satisfy the demand and its corresponding cost. (2 points per mistake)
- 4 points for managing to find the minimum cost of the mixed strategy of $89,110 (or $88,110).

c) Hire two employees			56	units produced per month						
idle time allowed										
Period		0	1	2	3	4	5	6	7	TOTAL
Forecast			50	44	55	60	60	40	50	359
Reg. Prod.	56		50	51	56	56	56	40	50	359
O.T. Prod.			0	0	0	0	0	0	0	0
Final Inventory		0	0	7	8	4	0	0	0	19
Backorder			0	0	0	0	0	0	0	0
Reg. Cost	$240		$12,000	$12,240	$13,440	$13,440	$13,440	$9,600	$12,000	$86,160
O.T Cost	$360		$0	$0	$0	$0	$0	$0	$0	$0
Inv. Cost	$50		$0	$350	$400	$200	$0	$0	$0	$950
Backorder Cost	$100		$0	$0	$0	$0	$0	$0	$0	$0
TOTAL			$12,000	$12,590	$13,840	$13,640	$13,440	$9,600	$12,000	$87,110
				Hiring/Firing Cost	Total Cost					
				$2,000	$89,110					
				or just						
				Cost of Hiring						
				$1,000	$88,110	--> Update to reflect hiring of 2 employees				

Transportation Method:

	March	April	May	June	July	August	September	Excess	Capacity
Initial	0	50	100	150	200	250	300		
Inventory								**0**	**0**
March	240	290	340	390	440	490	540		
(Regular)	**40**							**0**	**40**
	360	410	460	510	560	610	660		
(Overtime)	**8**							**0**	**8**
	420	470	520	570	620	670	720		
(Subcont.)	**2**							**10**	**12**
April	340	240	290	340	390	440	490		
(Regular)		**40**						**0**	**40**
	460	360	410	460	510	560	610		
(Overtime)		**4**	**4**					**0**	**8**
	520	420	470	520	570	620	670		
(Subcont.)								**12**	**12**
May	440	340	240	290	340	390	440		
(Regular)			**40**					**0**	**40**
	560	460	360	410	460	510	560		
(Overtime)			**8**					**0**	**8**
	620	520	420	470	520	570	620		
(Subcont.)			**3**					**9**	**12**
June	540	440	340	240	290	340	390		
(Regular)				**40**				**0**	**40**
	660	560	460	360	410	460	510		
(Overtime)				**8**				**0**	**8**
	720	620	520	420	470	520	570		
(Subcont.)				**12**				**0**	**12**
July	640	540	440	340	240	290	340		
(Regular)					**40**			**0**	**40**
	760	660	560	460	360	410	460		
(Overtime)					**8**			**0**	**8**
	820	720	620	520	420	470	520		
(Subcont.)					**12**			**0**	**12**
August	740	640	540	440	340	240	290		
(Regular)						**40**		**0**	**40**
	860	760	660	560	460	360	410		
(Overtime)							**2**	**6**	**8**
	920	820	720	620	520	420	470		
(Subcont.)								**12**	**12**
September	840	740	640	540	440	340	240		
(Regular)							**40**	**0**	**40**
	960	860	760	660	560	460	360		
(Overtime)							**8**	**0**	**8**
	1,020	920	820	720	620	520	420		
(Subcont.)								**12**	**12**
	0	**0**	**0**	**0**	**0**	**0**	**0**	**61**	**420**
Demand	**50**	**44**	**55**	**60**	**60**	**40**	**50**	**61**	**359**

d) 24 points: **<u>Deduct 2 points for each different type of error</u>**

- 12 points for the setting up the transportation Tableau (e.g. filling up the Table with the correct supply capacity, demand requested, and unit cost).

- 6 points for solving to find an initial feasible solution using the intuitive lowest-cost approach. If the student is not using the intuitive lowest cost method then deduct ALL five points.
- 6 points for stating the production plan and its cost. Produce 40 units regular production from month 1 to month 7. Produce 8 units in overtime from month1 to month5 and month7. Produce only 2 units in overtime in month6. Subcontract 2 units in month 1, 3 units in month 3 and 12 units in month 4 and month 5. (3 points)

The total production cost of such a strategy is **$97,680** **(3 points)**

Solution and Cost of the transportation method

Period		*0*	*March*	*April*	*May*	*June*	*July*	*August*	*September*	TOTAL
Forecast			50	44	55	60	60	40	50	359
Reg. Prod.	40		40	40	40	40	40	40	40	280
O.T. Prod.	8		8	8	8	8	8	2	8	50
subcontract	12		2	0	3	12	12	0	0	29
Final Inventory		0	0	4	0	0	0	2	0	6
Backorder			0	0	0	0	0	0	0	0
Reg. Cost	$240		$9,600	$9,600	$9,600	$9,600	$9,600	$9,600	$9,600	$67,200
O.T Cost	$360		$2,880	$2,880	$2,880	$2,880	$2,880	$720	$2,880	$18,000
Sub. Cost	$420		$840	$0	$1,260	$5,040	$5,040	$0	$0	$12,180
Inv. Cost	$50		$0	$200	$0	$0	$0	$100	$0	$300
Backorder Co	$100		$0	$0	$0	$0	$0	$0	$0	$0
TOTAL			$13,320	$12,680	$13,740	$17,520	$17,520	$10,420	$12,480	**$97,680**

e) 2 points

Should mention the strategy with the lowest cost (answer may vary between students).