

Final Project

**By,
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Part I: Pallets

Table 1: Mean of each Run

Facility	X1 Spaces	X2 Pallets	X3 Stations	Max Utilization	Min Utilization	Time in system	Time stdev	max ave time	min ave time
1	4	14	8	0.796	0.509	1700.4	556.64	134.08	69.84
2	5	14	8	0.835	0.436	1624.75	479.47	134.17	58.77
3	4	15	8	0.805	0.56	1592.55	461.92	132	76.45
4	5	15	8	0.808	0.431	1617.45	485.25	138.12	66.58
5	4	14	9	0.771	0.365	1668.05	590.4	124.48	65.79
7	5	14	9	0.702	0.345	1611.8	545.55	127.29	63.87
6	4	15	9	0.912	0.229	1603.3	556.02	145.6	52.1
8	5	15	9	0.929	0.328	1567.25	517.75	151.84	60.09

Table 2: Summary of Means per Section

Section	Max Utiliz	Min Utiliz	Time in system	max ave time	min ave time
8 stations	0.811	0.484	1633.8	134.59	67.91
9 stations	0.8285	0.317	1612.6	137.3	60.46
4 Spaces	0.821	0.415	1641.07	134.04	66.05
5 Spaces	0.8185	0.385	1605.31	137.85	62.33
14 Pallets	0.776	0.414	1651.25	130.01	64.57
15 Pallets	0.8635	0.387	1595.138	141.89	63.81

Initial Summary of Means Conclusion: The means between Sections appear to be in-line with each other. The greatest variances between columns are as follows:

1. Maximum Utility: 14 & 15 Pallets appear to have the greatest variance between the means.
2. Minimum Utility: 8 & 9 have the largest variance between the means with 8 stations having the higher of the two means.
3. Time in the System: All the means appear to have a significant variance between their counter part. The smaller of the two numbers per their respective appears to have the longest time in the system.
4. Max Average Runtime: Out of the 3 categories, the greatest variance is between the 14 & 15 Pallets, with 14 Pallets having the shortest average run time.
5. Minimum Average runtime: Stations and Spaces had the greatest variance in their means, with 4 & 14 of the respective groups having the larger shortest meantime.

Table 3: Summary of Means Combined

Stations	Pallets	Spaces	Max Utiliz	Min Utiliz	Time in system	max ave time	min ave time	
8	14	4	0.796	0.509	1700.4	134.08	69.84	
		5	0.835	0.436	1624.75	134.17	58.77	
	15	4	0.805	0.56	1592.55	132	76.45	
		5	0.808	0.431	1617.45	138.12	66.58	
	Total			0.811	0.484	1633.8	134.59	67.91
	9	14	4	0.771	0.365	1668.05	124.48	65.79
5			0.702	0.345	1611.8	127.29	63.87	
15		4	0.912	0.229	1603.3	145.6	52.1	
		5	0.929	0.328	1567.25	151.84	60.09	
Total			0.8285	0.317	1612.6	137.3	60.46	

Initial Means Combined Conclusion: We broke the means down into variations of the different runs we found that that there was more variation between the means. The greatest variances between columns are as follows:

1. Max Utilization: 9 stations and 15 pallets provide the highest Utilization.
2. Min Utilization: 9 Stations, 15 pallets and 4 Spaces produce the lowest percentage of minimum utilization of the stations. 8 Stations, 4 Spaces and (14 or 15) Pallets produce the lowest percentage of minimum utilization of the stations.
3. Time in the System: 8 Stations, 4 Spaces and 14 pallets provide the longest time in the system, while 9 Stations, 5 Spaces and 15 pallets provide the shortest time in the system. Between 14 & 15 Pallets, 15 Pallets are consistently smaller than its counterpart. 15 Pallets appear to have a longer Average Runtime.
4. Max Average Time: 9 Stations, 5 Spaces and 15 pallets provided the longest average run time for the workstation, while 9 Stations, 4 Spaces and 14 pallets provided the shortest average run time for the workstation
5. Minimum Average Runtime: 8 Stations, 4 Spaces and 14 pallets had the highest minimum runtime for the workstations, while 9 Stations, 4 Spaces and 15 pallets had the lowest average runtime for the workstations.

Regression Analysis

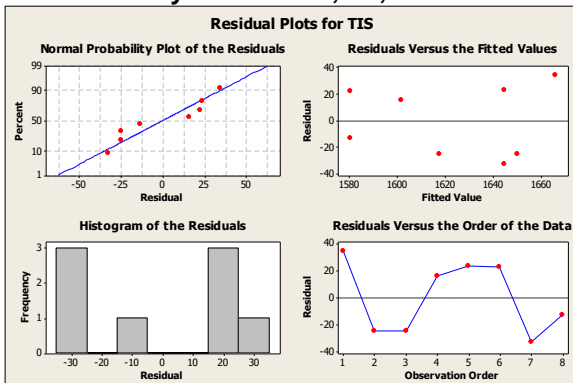
X1 = Spaces

X2 = Pallets

X3 = Stations

Regression Analysis:

Time in the System vs. X1, X2, X3



Note: The Normal plot of the residual is close to linear. The residuals for each run seem to have no trend.

The regression equation is
 $TIS = 2573 - 15.9 X1 - 48.1 X2 - 21.2 X3$

Predictor	Coef	SE Coef	T	P
Constant	2573.1	428.9	6.00	0.004
X1	-15.94	28.94	-0.55	0.611
X2	-48.14	28.94	-1.66	0.172
X3	-21.19	25.07	-0.85	0.446

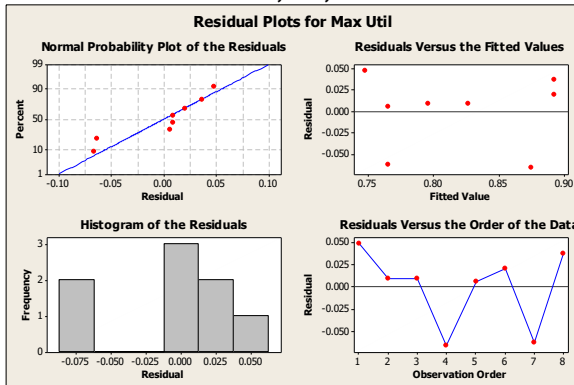
S = 35.4485 R-Sq = 60.1% R-Sq(adj) = 30.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	7576	2525	2.01	0.255
Residual Error	4	5026	1257		
Total	7	12603			

Source	DF	Seq SS
X1	1	3202
X2	1	3476
X3	1	898

Regression Analysis: Max Utilization vs. X1, X2, X3



Note: The Normal plot of the residual is close to linear. The residuals for each run seem to have no trend.

The regression equation is
 $Max Util = -0.382 + 0.0783 X1 + 0.0483 X2 + 0.0175 X3$

Predictor	Coef	SE Coef	T	P
Constant	-0.3823	0.6821	-0.56	0.605
X1	0.07833	0.04603	1.70	0.164
X2	0.04833	0.04603	1.05	0.353
X3	0.01750	0.03986	0.44	0.683

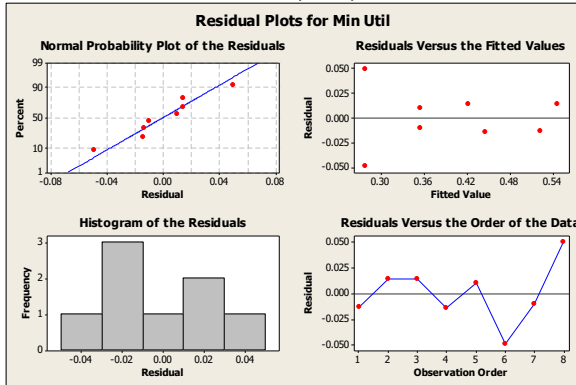
S = 0.0563701 R-Sq = 66.4% R-Sq(adj) = 41.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.025129	0.008376	2.64	0.186
Residual Error	4	0.012710	0.003178		
Total	7	0.037839			

Source	DF	Seq SS
X1	1	0.021012
X2	1	0.003504
X3	1	0.000613

Regression Analysis: Min Utilization vs. X1, X2, X3



Note: The Normal plot of the residual is close to linear. The residuals for each run seem to have no trend.

The regression equation is

$$\text{Min Util} = 1.93 - 0.101 X1 + 0.0235 X2 - 0.167 X3$$

Predictor	Coef	SE Coef	T	P
Constant	1.9335	0.4641	4.17	0.014
X1	-0.10050	0.03132	-3.21	0.033
X2	0.02350	0.03132	0.75	0.495
X3	-0.16725	0.02712	-6.17	0.004

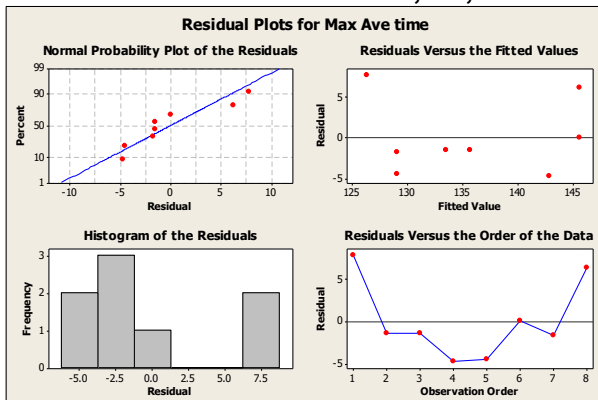
S = 0.0383577 R-Sq = 92.5% R-Sq(adj) = 86.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.072527	0.024176	16.43	0.010
Residual Error	4	0.005885	0.001471		
Total	7	0.078412			

Source	DF	Seq SS
X1	1	0.015753
X2	1	0.000828
X3	1	0.055945

Regression Analysis: Max Ave Run Time versus X1, X2, X3



Note: The Normal plot of the residual is close to linear. The residuals for each run seem to have no trend.

The regression equation is

$$\text{Max Ave time} = -33.7 + 9.37 X1 + 7.20 X2 + 2.71 X3$$

Predictor	Coef	SE Coef	T	P
Constant	-33.65	74.16	-0.45	0.674
X1	9.370	5.004	1.87	0.134
X2	7.200	5.004	1.44	0.224
X3	2.710	4.334	0.63	0.566

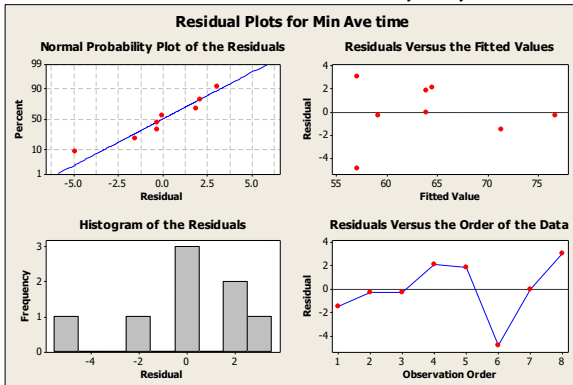
S = 6.12898 R-Sq = 74.1% R-Sq(adj) = 54.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	428.89	142.96	3.81	0.115
Residual Error	4	150.26	37.56		
Total	7	579.15			

Source	DF	Seq SS
X1	1	336.44
X2	1	77.76
X3	1	14.69

**Regression Analysis:
Min Ave Run Time versus X1, X2, X3**



Note: The Normal plot of the residual is close to linear. The residuals for each run seem to have no trend.

The regression equation is

$$\text{Min Ave time} = 105 - 12.3 X1 + 5.38 X2 - 7.45 X3$$

Predictor	Coef	SE Coef	T	P
Constant	104.74	40.18	2.61	0.060
X1	-12.295	2.712	-4.53	0.011
X2	5.385	2.712	1.99	0.118
X3	-7.448	2.348	-3.17	0.034

S = 3.32096 R-Sq = 88.5% R-Sq(adj) = 79.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	338.84	112.95	10.24	0.024
Residual Error	4	44.12	11.03		
Total	7	382.96			

Source	DF	Seq SS
X1	1	184.42
X2	1	43.50
X3	1	110.93

Regression Equations summary

- TIS = 2573 - 15.9 X1 - 48.1 X2 - 21.2 X3
- Max Util = - 0.382 + 0.0783 X1 + 0.0483 X2 + 0.0175 X3
- Min Util = 1.93 - 0.101 X1 + 0.0235 X2 - 0.167 X3
- Max Ave time = - 33.7 + 9.37 X1 + 7.20 X2 + 2.71 X3
- Min Ave time = 105 - 12.3 X1 + 5.38 X2 - 7.45 X3

Correlations: Max Utilization, Min Utilization, Max Ave Run Time, Min Ave Run Time, Time in the System

	Max Util	Min Util	Max Ave time	Min Ave time
Min Util	-0.371 0.365			
Max Ave time	0.909 0.002	-0.408 0.316		
Min Ave time	-0.533 0.174	0.872 0.005	-0.513 0.194	
TIS	-0.462 0.249	0.314 0.449	-0.568 0.142	0.266 0.525

Cell Contents: Pearson correlation
P-Value

Correlation conclusion:

There appears to be some correlation between the Min Average Run Time and the Time in the System and some correlation between the Min Utilization and the Min Time in the System.

ANOVA Test for significant level of .05

Time In the System

$H_0: \mu_1 = \mu_2 = \dots = \mu_8$

H_1 : At least two of the means are not equal.

$\alpha = 0.05$

Critical Region: $f > 6.59$ with $v_1 = 3$ and $v_2 = 4$ degrees of freedom.

The sums of squares computations give:

$$SST = 12603$$

$$SSA = 7576$$

$$SSE = 5026$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	7576	2525	2.01	0.255
Residual Error	4	5026	1257		
Total	7	12603			

Decision: Do not reject H_0 and conclude that the aggregates do have the same mean. The P- value for $f = 2.01$ which is 0.255 is larger than 0.05.

Max of Utilization of workstation

$H_0: \mu_1 = \mu_2 = \dots = \mu_8$

H_1 : At least two of the means are not equal.

$\alpha = 0.05$

Critical Region: $f > 6.59$ with $v_1 = 3$ and $v_2 = 4$ degrees of freedom.

The sums of squares computations give:

$$SST = 0.037839$$

$$SSA = 0.025129$$

$$SSE = 0.012710$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.025129	0.008376	2.64	0.186
Residual Error	4	0.012710	0.003178		
Total	7	0.037839			

Decision: Do not reject H_0 and conclude that the aggregates do have the same mean. The P- value for $f= 2.64$ which is 0.186 is larger than 0.05.

Minimum Utilization of workstation

$H_0: \mu_1 = \mu_2 = \dots = \mu_8$

H_1 : At least two of the means are not equal.

$\alpha = 0.05$

Critical Region: $f > 6.59$ with $v_1 = 3$ and $v_2 = 4$ degrees of freedom.

The sums of squares computations give:

$$SST = 0.078412$$

$$SSA = 0.072527$$

$$SSE = 0.005885$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.072527	0.024176	16.43	0.010
Residual Error	4	0.005885	0.001471		
Total	7	0.078412			

Decision: Reject H_0 and conclude that the aggregates do not have the same mean. The P- value for $f= 16.43$ which is 0.01 is smaller than 0.05.

MAX Average Run Time of Workstations

$H_0: \mu_1 = \mu_2 = \dots = \mu_8$

H_1 : At least two of the means are not equal.

$\alpha = 0.05$

Critical Region: $f > 6.59$ with $v_1 = 3$ and $v_2 = 4$ degrees of freedom.

The sums of squares computations give:

$$SST = 579.15$$

$$SSA = 150.26$$

$$SSE = 428.89$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	428.89	142.96	3.81	0.115
Residual Error	4	150.26	37.56		
Total	7	579.15			

Decision: Do not reject H_0 and conclude that the aggregates do have the same mean. The P- value for $f= 3.81$ which is 0.115 is larger than 0.05.

MIN Average Run Time of Workstations

$H_0: \mu_1 = \mu_2 = \dots = \mu_8$

H_1 : At least two of the means are not equal.

$\alpha = 0.05$

Critical Region: $f > 6.59$ with $v_1 = 3$ and $v_2 = 4$ degrees of freedom.

The sums of squares computations give:

$$SST = 338.84$$

$$SSA = 44.12$$

$$SSE = 382.96$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	338.84	112.95	10.24	0.024
Residual Error	4	44.12	11.03		
Total	7	382.96			

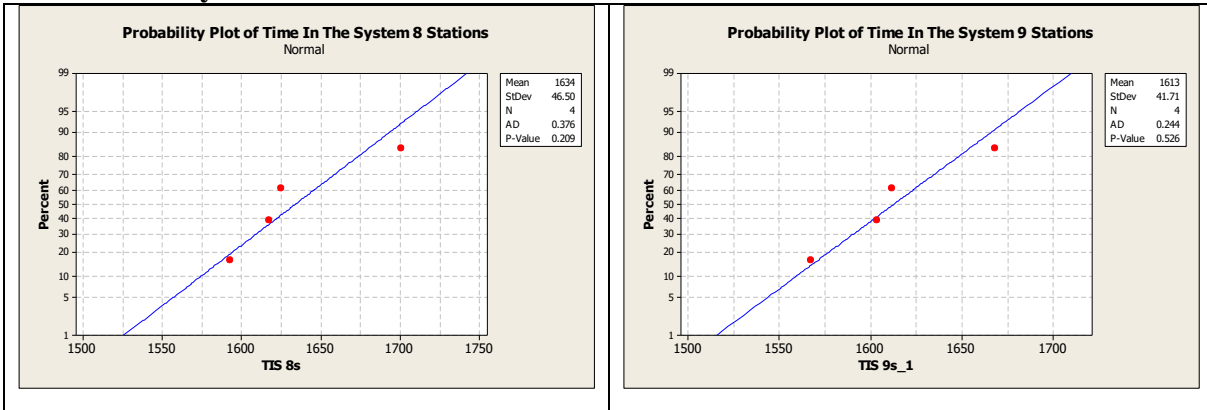
Decision: Reject H_0 and conclude that the aggregates do not have the same mean. The P- value for $f= 10.24$ which is 0.024 is smaller than 0.05.

Summary:

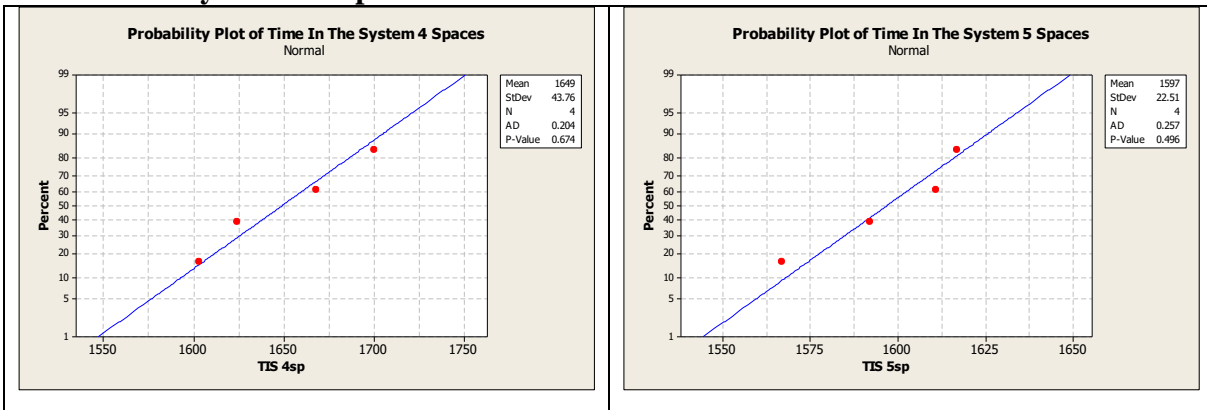
1. All of the means for the minimum utilization are not the same
2. All of the means for the minimum Average run Time are not the same

Conclusion: The ANOVA test indicates that all of the means for the given sections are equal except for the minimum utilization and the minimum average run time of the workstation. At least one out of 8 runs, for the respective sections, are different from the remaining 7 runs.

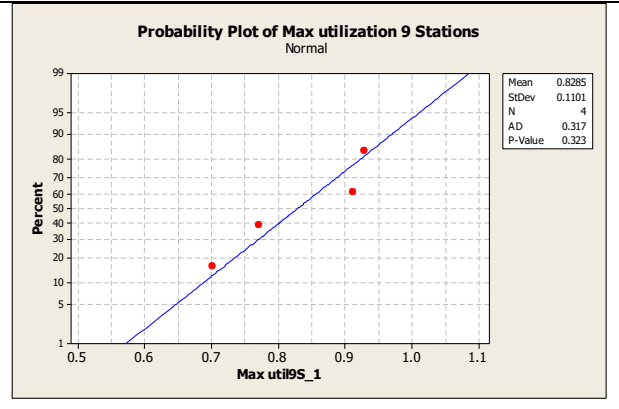
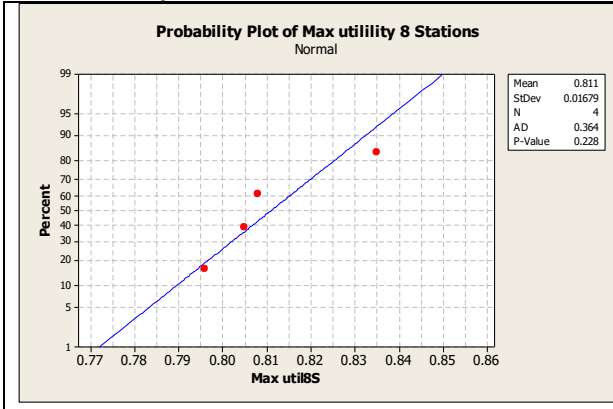
**Normal Test
Anderson Darling Test
Time in the System 8/9 Stations**



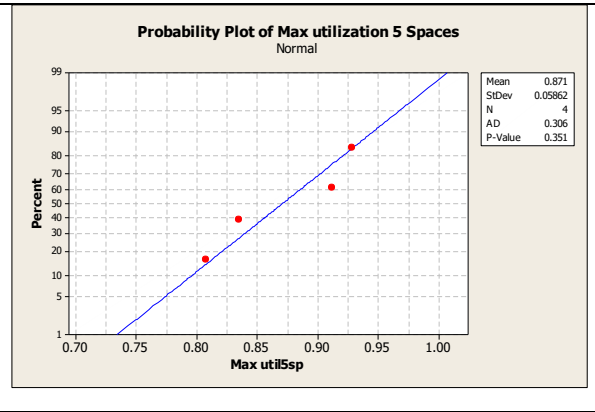
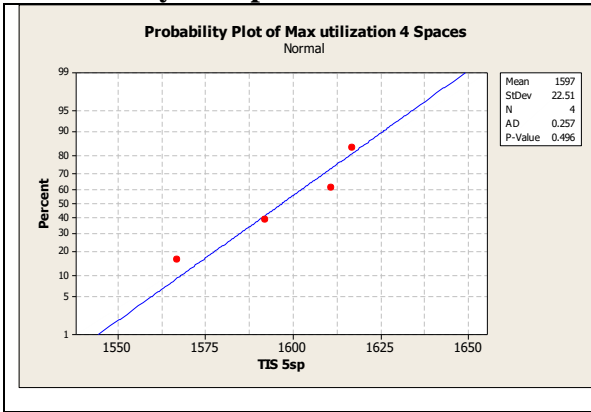
Time in the System 4/5 Spaces



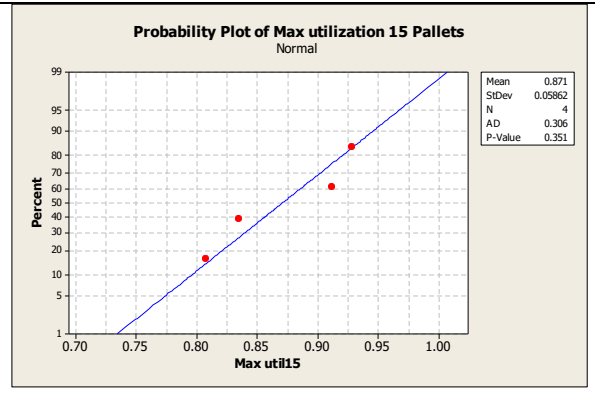
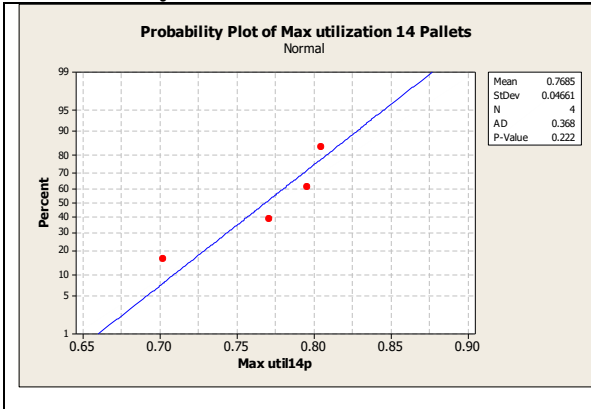
Max Utility 8/9 Stations



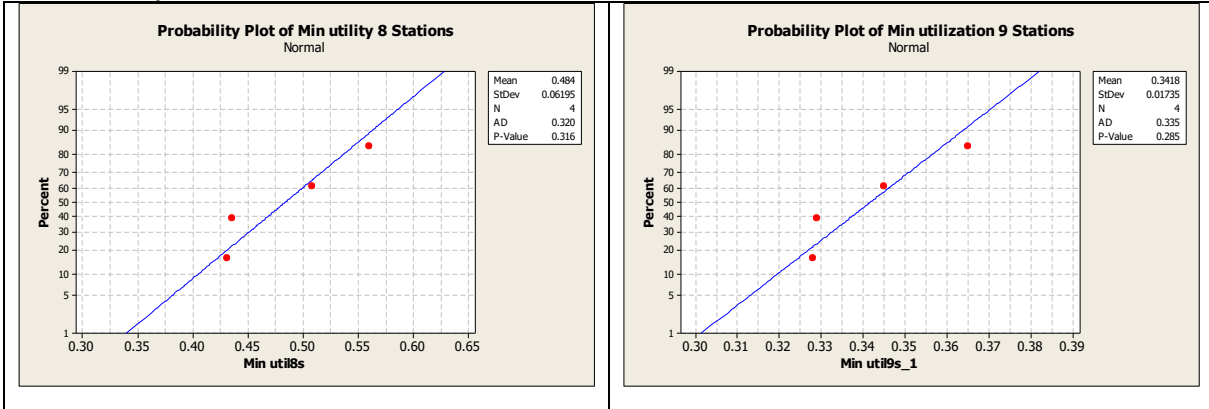
Max Utility 4/5 Spaces



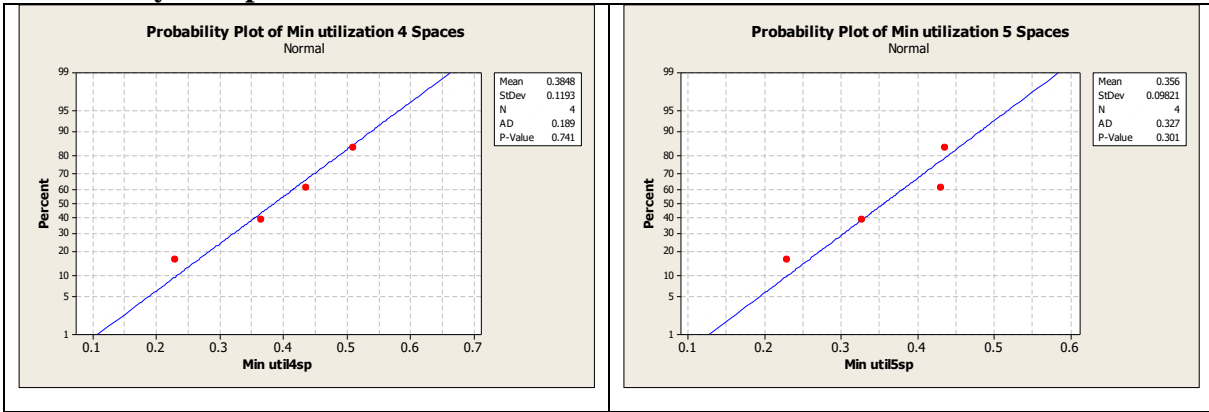
Max Utility 14/15 Pallets



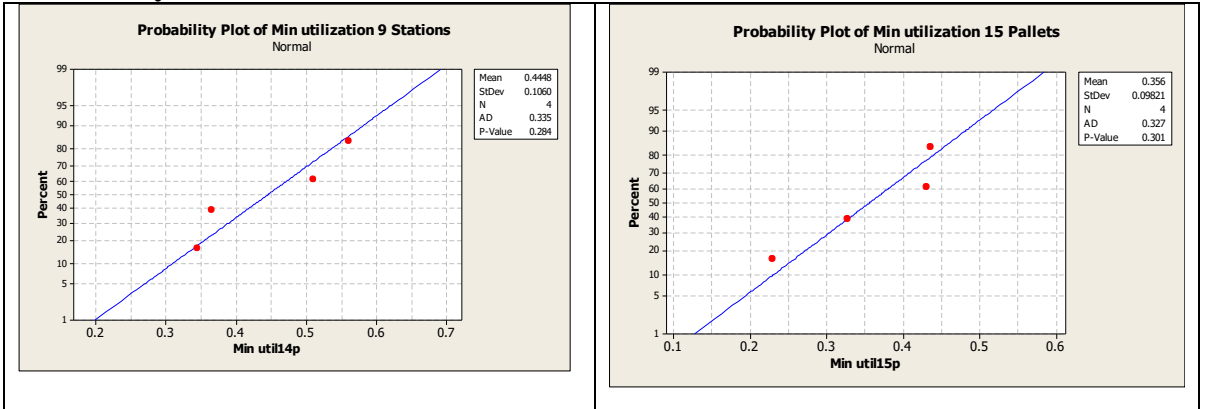
Min Utility 8/9 Stations



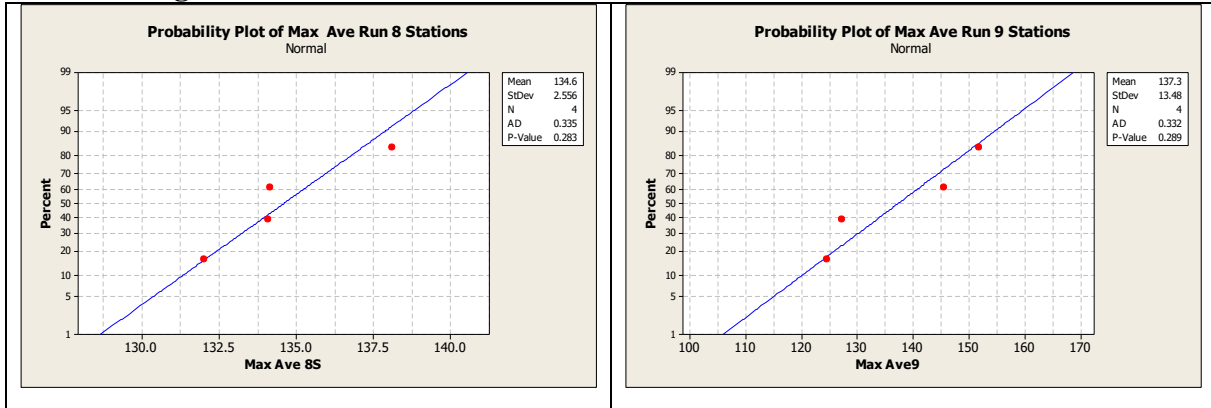
Min Utility 4/5 Spaces



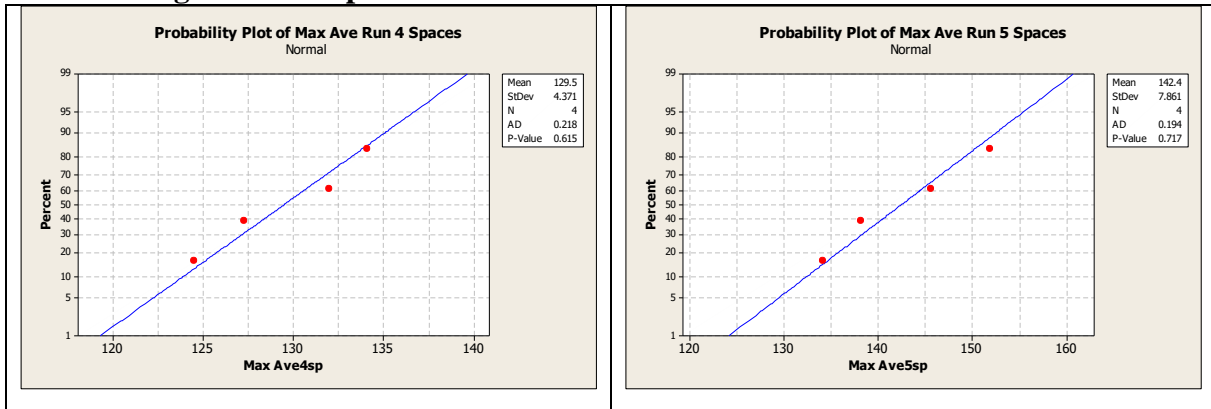
Min Utility 14/15 Pallets



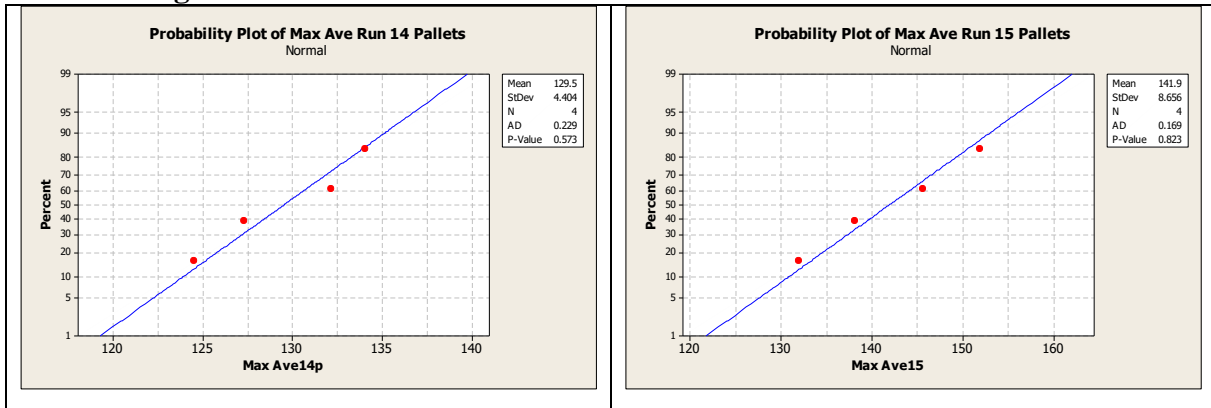
Max Average Run 8/9 Stations



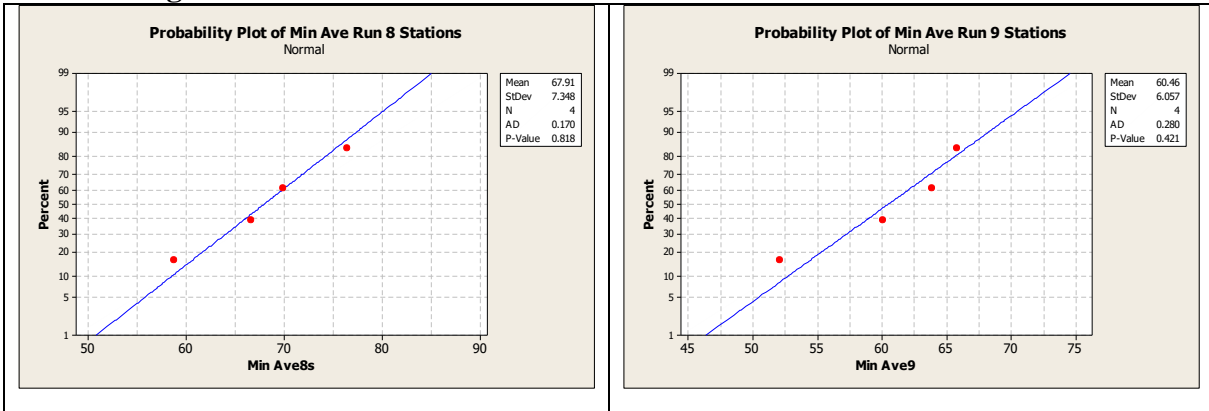
Max Average Run 4/5 Spaces



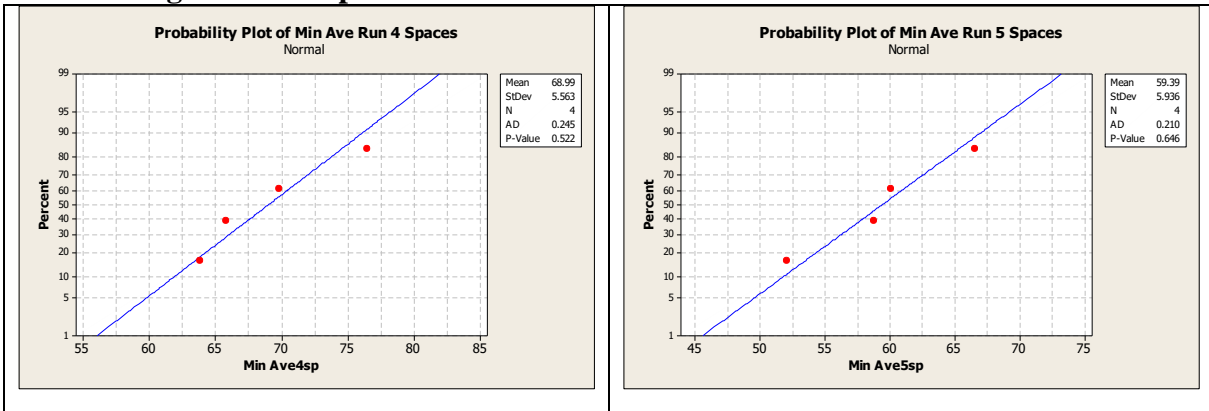
Max Average Run 14/15 Pallets



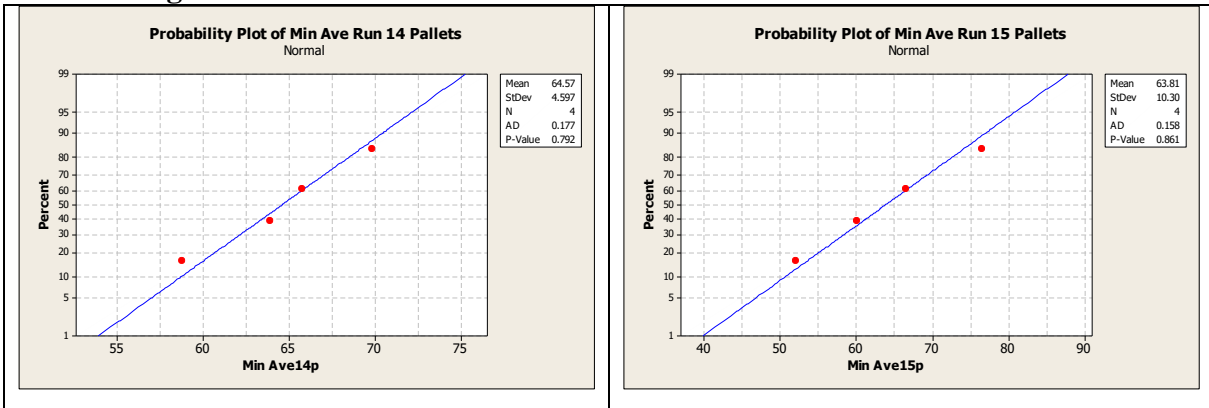
Min Average Run 8/9 Stations



Min Average Run 4/5 Spaces



Min Average Run 14/15 Pallets



Conclusion: Most of the samples were indeed Normal Distribution. We did find a few samples that were not Normally Distributed, but the significant interval and the probability were so close that with more samples they could be Normal samples. Considering the data we have and the additional test we have to conduct, we will assume that the data is indeed Distributed Normal.

Two-Sample T-Test and CI

95% CI for difference

Time In the System

Stations

Difference = μ (TIS 8s) - μ (TIS 9s_1)

Estimate for difference: 21.1875

95% CI for difference: (-59.0954, 101.4704)

T-Test of difference = 0 (vs not =): T-Value = 0.68 P-Value = 0.528 DF = 5

Means are the same

Spaces

Difference = μ (TIS 4sp) - μ (TIS 5sp)

Estimate for difference: 27.3625

95% CI for difference: (-47.8499, 102.5749)

T-Test of difference = 0 (vs not =): T-Value = 1.01 P-Value = 0.370 DF = 4

Means are the same

Pallets

Difference = μ (TIS 14p) - μ (TIS 15p)

Estimate for difference: 56.1125

95% CI for difference: (-7.5311, 119.7561)

T-Test of difference = 0 (vs not =): T-Value = 2.45 P-Value = 0.071 DF = 4

Means are the same

Max Utilization

Stations

Difference = μ (Max util8S) - μ (Max util9S)

Estimate for difference: -0.017500

95% CI for difference: (-0.194755, 0.159755)

T-Test of difference = 0 (vs not =): T-Value = -0.31 P-Value = 0.774 DF = 3

Means are the same

Spaces

Difference = μ (Max util4sp) - μ (Max util5sp)

Estimate for difference: -0.102500

95% CI for difference: (-0.198760, -0.006240)

T-Test of difference = 0 (vs not =): T-Value = -2.74 P-Value = 0.041 DF = 5

The Maximum Utilization of 5 spaces is greater than 4 spaces

Pallets

Difference = mu (Max util14p) - mu (Max util15p)
Estimate for difference: -0.087500
95% CI for difference: (-0.198876, 0.023876)
T-Test of difference = 0 (vs not =): T-Value = -2.02 P-Value = 0.099 DF = 5
Means are the same

Min Utilization

Stations

Difference = mu (Min util8s) - mu (Min util9s_1)
Estimate for difference: 0.167250
95% CI for difference: (0.056023, 0.278477)
T-Test of difference = 0 (vs not =): T-Value = 3.87 P-Value = 0.012 DF = 5

The Minimum Utilization of 8 stations is greater than 9 stations

Spaces

Difference = mu (Min util4sp) - mu (Min util5sp)
Estimate for difference: 0.088750
95% CI for difference: (-0.097001, 0.274501)
T-Test of difference = 0 (vs not =): T-Value = 1.23 P-Value = 0.274 DF = 5

Means are the same

Pallets

Difference = mu (Min util14p) - mu (Min util15p)
Estimate for difference: 0.026750
95% CI for difference: (-0.195627, 0.249127)
T-Test of difference = 0 (vs not =): T-Value = 0.33 P-Value = 0.755 DF = 4

Means are the same

Max Average Run Time

Stations

Difference = mu (Max Ave 8S) - mu (Max Ave9)
Estimate for difference: -2.71000
95% CI for difference: (-24.53664, 19.11664)
T-Test of difference = 0 (vs not =): T-Value = -0.40 P-Value = 0.719 DF = 3

Means are the same

Spaces

Difference = mu (Max Ave4sp) - mu (Max Ave5sp)
Estimate for difference: -12.9700
95% CI for difference: (-25.4564, -0.4836)
T-Test of difference = 0 (vs not =): T-Value = -2.88 P-Value = 0.045 DF = 4

The Max Average Run Time for 5 spaces is greater than 4 spaces

Pallets

Difference = μ (Max Ave14p) - μ (Max Ave15)
Estimate for difference: -11.8850
95% CI for difference: (-25.6893, 1.9193)
T-Test of difference = 0 (vs not =): T-Value = -2.39 P-Value = 0.075 DF = 4

Means are the same

Min Average Run Time

Stations

Difference = μ (Min Ave8s) - μ (Min Ave9)
Estimate for difference: 7.44750
95% CI for difference: (-4.79156, 19.68656)
T-Test of difference = 0 (vs not =): T-Value = 1.56 P-Value = 0.179 DF = 5

Means are the same

Spaces

Difference = μ (Min Ave4sp) - μ (Min Ave5sp)
Estimate for difference: 9.60250
95% CI for difference: (-0.85356, 20.05856)
T-Test of difference = 0 (vs not =): T-Value = 2.36 P-Value = 0.065 DF = 5

Means are the same

Pallets

Difference = μ (Min Ave14p) - μ (Min Ave15p)
Estimate for difference: 0.762500
95% CI for difference: (-14.898311, 16.423311)
T-Test of difference = 0 (vs not =): T-Value = 0.14 P-Value = 0.899 DF = 4

Means are the same

Conclusion: All of the means of the Runs appear to be the same except the following;

1. The Maximum Utilization of 5 spaces is greater than 4 spaces
2. The Minimum Utilization of 9 stations is greater than 8 stations
3. The Max Average Run Time for 5 spaces is greater than 4 spaces

From the Confidence Intervals we would conclude that we could obtain the maximum utilization and Maximum average run time with 8 stations and 5 spaces. For this test, the Pallets are not significant.

Predicted Interval Estimation

X1 = 4 Spaces; X2 = 12 Pallets; X3 = 7 Stations

TIS = 2573 - 15.9 X1 - 48.1 X2 - 21.2 X3

TIS = 2080.2

Max Util = - 0.382 + 0.0783 X1 + 0.0483 X2 + 0.0175 X3

Max Util = .6333

Min Util = 1.93 - 0.101 X1 + 0.0235 X2 - 0.167 X3

Min Util = .639

Max Ave time = - 33.7 + 9.37 X1 + 7.20 X2 + 2.71 X3

Max Ave time = 109.15

Min Ave time = $105 - 12.3 X1 + 5.38 X2 - 7.45 X3$

Min Ave time = 68.21

Recommendation to the Owner

Time in the System

The data above indicates that the mean time in the system did not vary between the various sections. We find that the combined sections indicated that 9 stations, 15 Pallets and 5 Spaces provided the lowest overall Time in the System.

Maximum utilization of the Stations

The data above indicates that the means of Maximum Utilization of the Stations did vary between 4 and 5 Spaces with 5 Spaces having the better of the two sections.

Minimum Utilization of the Stations

The data above indicates that the means of Minimum Utilization of the Stations did vary between the 8 and 9 Stations, with 8 having the better of the two sections.

Maximum Average Run Time

The data above indicates that the means of Maximum Average Run Time did vary between 4 and 5 Spaces with 5 Spaces having the better of the two sections. We find that the combined sections indicated that 9 stations, 15 Pallets and 5 Spaces provided the highest Maximum Average Run Time.

Minimum Average Run Time

The data above indicates that the mean Minimum Average Run Time did not vary between the various sections. We find that the combined sections indicated that 9 stations, 15 Pallets and 5 Spaces provided the lowest overall Minimum Average Run

Pallets Final Conclusion

In order to optimize production and reduce cost we recommend the following; Provide 9 stations, 15 Pallets and 5 Spaces. With this configuration, the combined data indicates that the mean Time in the System will be equal if not less, the Utilization will be maximized, and the Average runtime of the Stations will be optimized. This will make for the most efficient way to operate the production line. This assembly model appears to be inline with the "predicted assembly line of 4 Spaces, 12 Pallets & 7 Stations" which indicates; if we reduce the stations, Spaces and Pallets, our overall Time in the System will increase and the utilization and Average run time will decrease.

Part II: ANOVA model for the Manuf1.gps

I.)

The Data

Run	Operator	Machine	Tsys	Util of clerk	Util of operators	Util of machines
1	7	3	7967	0.141	1	0.072
2	7	3	7926	0.143	1	0.074
3	7	4	7967	0.141	1	0.054
4	7	4	7926	0.143	1	0.056
5	6	3	8154	0.081	1	0.012
6	6	3	6959	0.052	1	0
7	6	4	8154	0.081	1	0.009
8	6	4	6959	0.052	1	0
9	6	5	8154	0.081	1	0.007
10	6	5	6959	0.052	1	0

Interpretation of Output

Oper	Mach	Mean-Tsys	Std. Dev-Tsys	Mean-UtilC	Std. Dev-Clerk	Mean-UtilO	Std. Dev-O	Mean-UtilM	Std. Dev-M	N
7	3	7946.5	28.99	0.142	0.0014	1	0	0.073	0.0014	2
	4	7946.5	28.99	0.142	0.00141	1	0	0.055	0.0014	2
	Total	7946.5	23.67	0.142	0.001155	1	0	0.064	0.010456	4
6	3	7556.5	844.993	0.0665	0.0205	1	0	0.006	0.008485281	2
	4	7556.5	844.993	0.0665	0.0205	1	0	0.0045	0.006363961	2
	5	7556.5	844.993	0.0665	0.0205	1	0	0.0035	0.004949747	2
	Total	7556.5	654.53	0.0665	0.016	1	0	0.004667	0.005354	6
Total	3	7751.5	537.57	0.10425	0.0135	1	0	0.0395	0.039	4
	4	7751.5	537.57	0.10425	0.0135	1	0	0.02975	0.029	4
	5	7556.5	844.993	0.0665	0.0205	1	0	0.0035	0.004949747	2
	Total	7712.5	527.97	0.0967	0.0408	1	0	0.0284	0.0315	10

An analysis of these means reveals that for mean times in the system, there is no difference between the marginal means of 3 and 4 machines across the levels of operator, but there is difference between 5 machines across the levels of operator and the rest. The marginal means of operator over levels machine are different (7946.5 vs. 7556.5) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased.

For utilization of the clerk, there is no difference between the marginal means of 3 and 4 machines across the levels of operator, but there is difference between 5 machines across the levels of operator and the rest. The marginal means of operator over levels machine are different (0.142 vs. 0.0665) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased.

For utilization of the operators, there is no difference between the marginal means across the levels of operator. Same as the marginal means of operator over levels machine which is no difference.

For utilization of the machines, there are different between the marginal means of machines across the levels of operator (0.0395 vs. 0.02975). The marginal means of operator over levels machine are also different (0.010456 vs. 0.005354) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased as well.

ANOVA Model

Times in the System:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Tsys	10	10	0	10	7712.500	527.969

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	4 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 2

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

$$\text{Tsys} = 5217 + 390 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	5217	15288	0.34	0.745
Operator	390	2440	0.16	0.878
Machine	-0	4152	-0.00	1.000
interact	0.0	668.3	0.00	1.000

Analysis of Variance for Tsys, using Adjusted SS for Tests

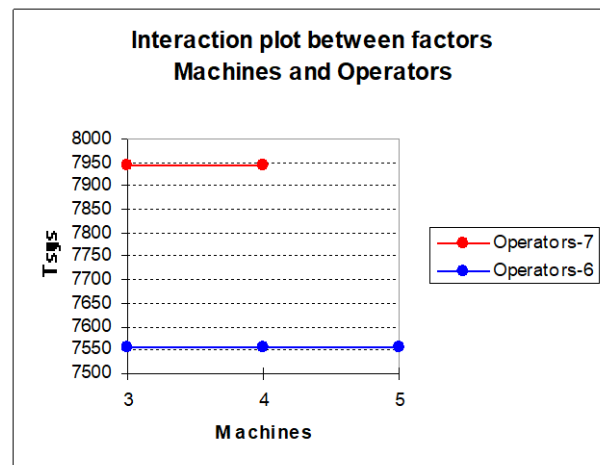
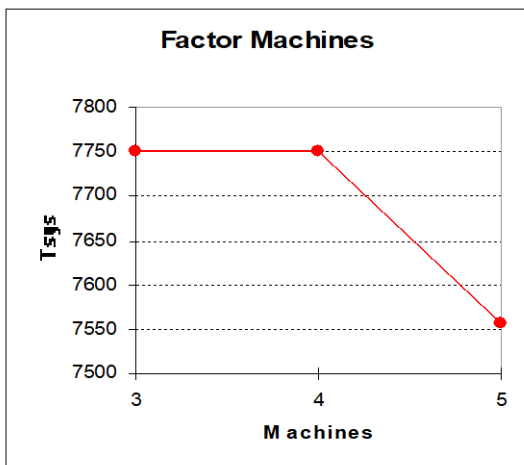
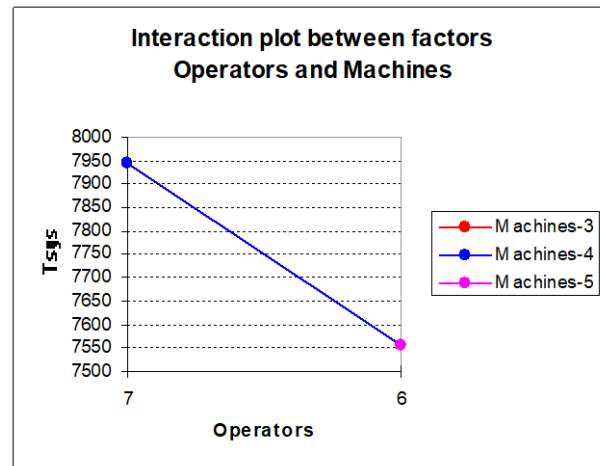
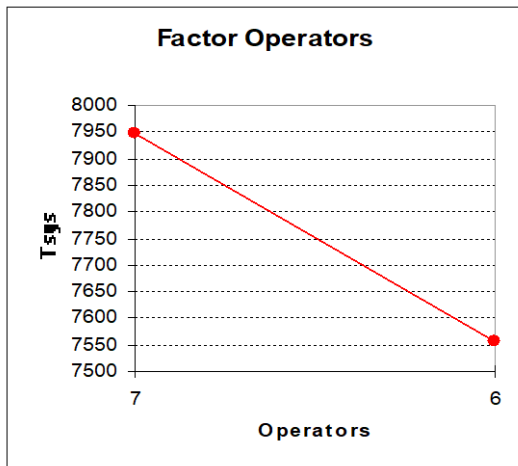
Source	Model DF	Reduced DF	Seq SS	MS	F	P
Operator	1	1	365040	365040	0.851	0.398
Machine	2	2	0	0	0	1
Operator*Machine	2	1+	0	0	0	1
Error	4	5	2143718	428743.60		
Total	9	9	2508758			

S = 654.785 R-Sq = 14.55% R-Sq(adj) = 0.00%

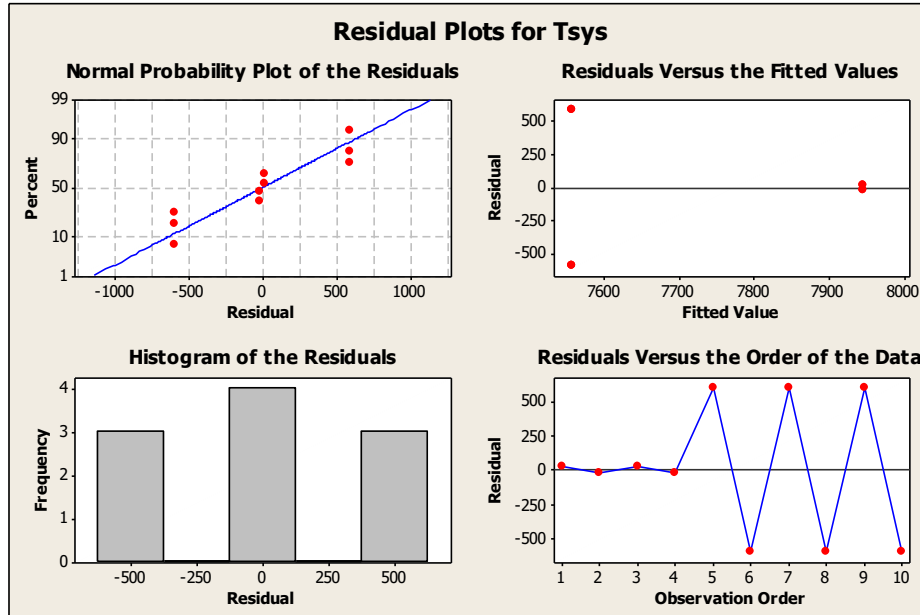
Estimated Values:

Run	Tsys	Tsys (Model)
1	7967	7947
2	7926	7947
3	7967	7947
4	7926	7947
5	8154	7557
6	6959	7557
7	8154	7557
8	6959	7557
9	8154	7557
10	6959	7557

Charts of the means:



Residual Plots:



The difference between the actual values and the values predicted by the regression equation can be divided in 3 groups; -500, 0, and 500. Run1 to Run4 don't have much difference between the actual values and estimated values since the residuals are around zero.

Conclusion:

From the ANOVA model, the machines factor and interaction factor between operators and machines have no effect with the mean times in the system. Although it seems that there is different when machine factor is 5 across the level of operator, there is no different between each machine factors with 6 operators. This model is unbalanced. We don't have information for 5 machines with 7 operators.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is not significant ($F=0, p=1$). This indicates that the effect of Operators does not depend on the level of Machines and vice versa. Therefore, the tests for the individual effects aren't valid, showing no significant Operators effect ($F=0.851, p=0.398$) and also no significant Machines effect ($F=0, p=1$).

We concluded that operators, machines and their interaction have no significant effect to times in the system.

Utilization of Clerk:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Util-Clerk	10	10	0	10	0.097	0.041

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	4 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 2

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

$$\text{Util-Clerk} = - 0.386 + 0.0755 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	-0.3865	0.3714	-1.04	0.338
Operator	0.07550	0.05929	1.27	0.250
Machine	-0.0000	0.1009	-0.00	1.000
interact	0.00000	0.01624	0.00	1.000

Analysis of Variance for Util-Clerk, using Adjusted SS for Tests

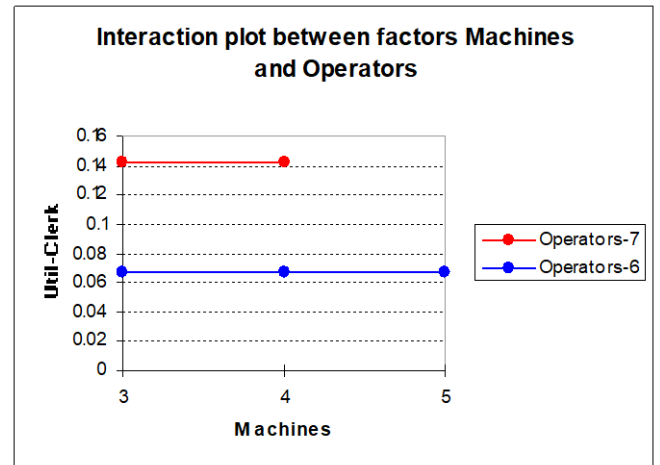
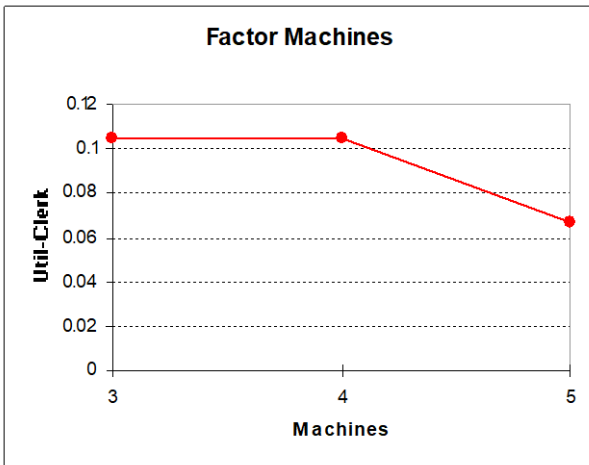
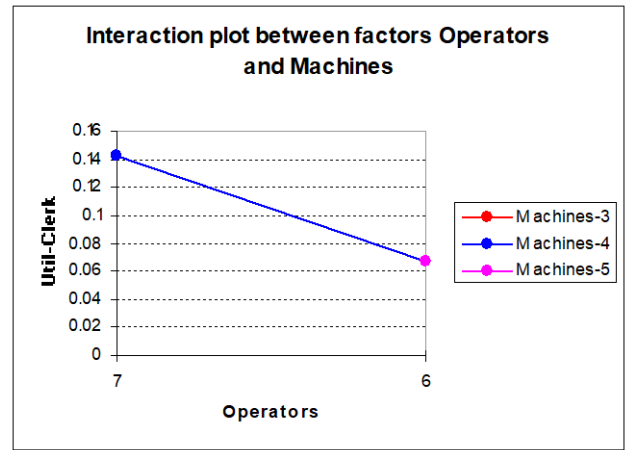
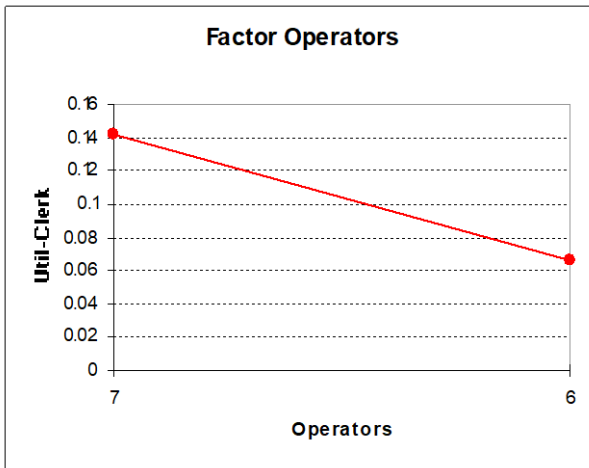
Source	Model DF	Reduced DF	Seq SS	MS	F	P
Operator	1	1	0.0136806	0.0136806	54.052	0.0007
Machine	2	2	0.0000000	0	0	1
Operator*Machine	2	1+	0.0000000	0	0	1
Error	4	5	0.0012655	0.0002531		
Total	9	9	0.0149461			

S = 0.0159091 R-Sq = 91.53% R-Sq(adj) = 84.76%

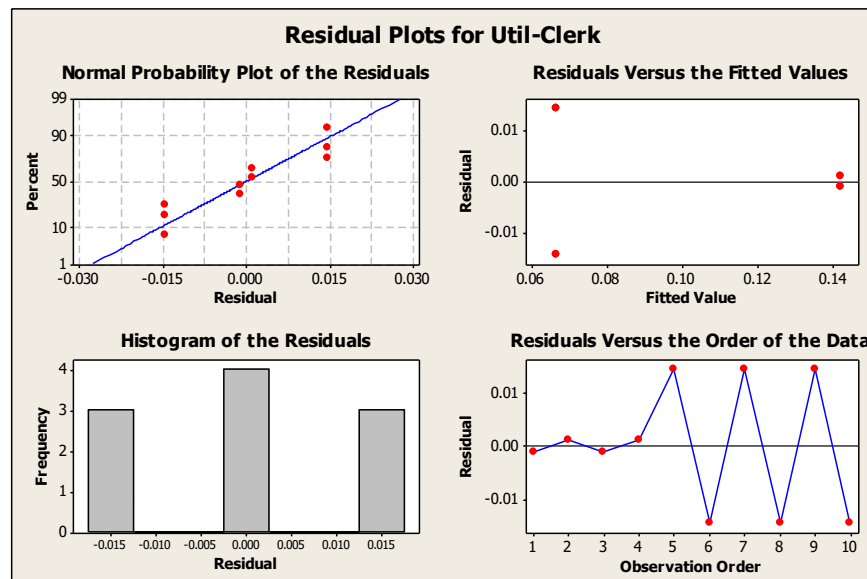
Estimated Values:

Run	Util-Clerk	Util-Clerk (Model)
1	0.141	0.1425
2	0.143	0.1425
3	0.141	0.1425
4	0.143	0.1425
5	0.081	0.067
6	0.052	0.067
7	0.081	0.067
8	0.052	0.067
9	0.081	0.067
10	0.052	0.067

Charts of the means:



Residual Plots:



The difference between the actual values and the values predicted by the regression equation can be divided in 3 groups; -0.015, 0, and 0.015. Run1 to Run4 don't have much difference between the actual values and estimated values since the residuals are around zero.

Conclusion:

Same as the conclusion of times in the system by analyzing the ANOVA model, the machines factor and interaction factor between operators and machines have no effect with the utilization of the clerk. Although it seems that there is different when machine factor is 5 across the level of operator, there is no different between each machine factors with 6 operators. This model is unbalanced. We don't have information for 5 machines with 7 operators.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is not significant ($F=0, p=1$). This indicates that the effect of Operators does not depend on the level of Machines and vice versa. The test for the operator effect is valid, showing a significant Operators effect ($F=54.052, p=0.001$). On the other hand, the test for the machine effect isn't valid, showing no significant Machines effect ($F=0, p=1$).

We concluded that only operator has a significant effect to the utilization of clerk.

Utilization of Operator:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Util-Oper	10	10	0	10	1	0

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	4 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 2

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

$$\text{Util-Oper} = 1 - 0 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	1.00000	0.00000	*	*
Operator	-0.00000000	0.00000000	*	*
Machine	-0.00000000	0.00000000	*	*
interact	0.00000000	0.00000000	*	*

Analysis of Variance for Util-Oper, using Adjusted SS for Tests

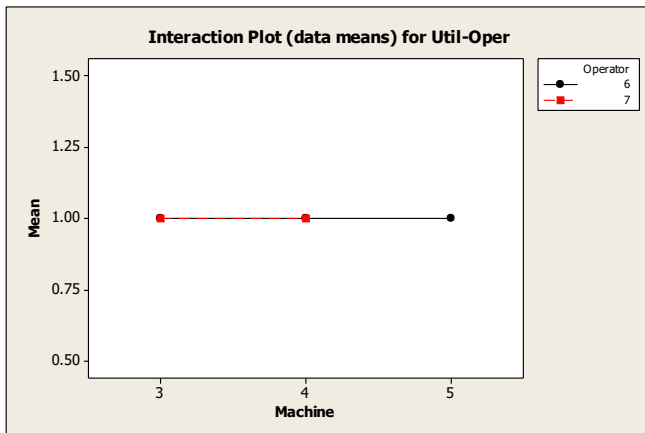
Source	DF	Reduced DF	Seq SS
Operator	1	1	0.0000000
Machine	2	2	0.0000000
Operator*Machine	2	1+	0.0000000
Error	4	5	0.0000000
Total	9	9	0.0000000

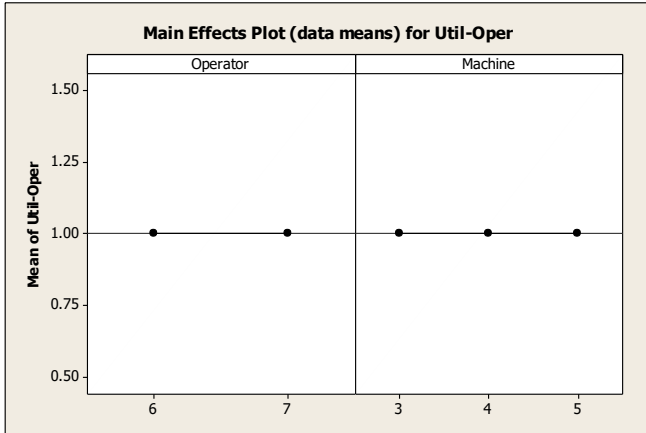
S = 0 R-Sq = *% R-Sq(adj) = *%

Estimated Values:

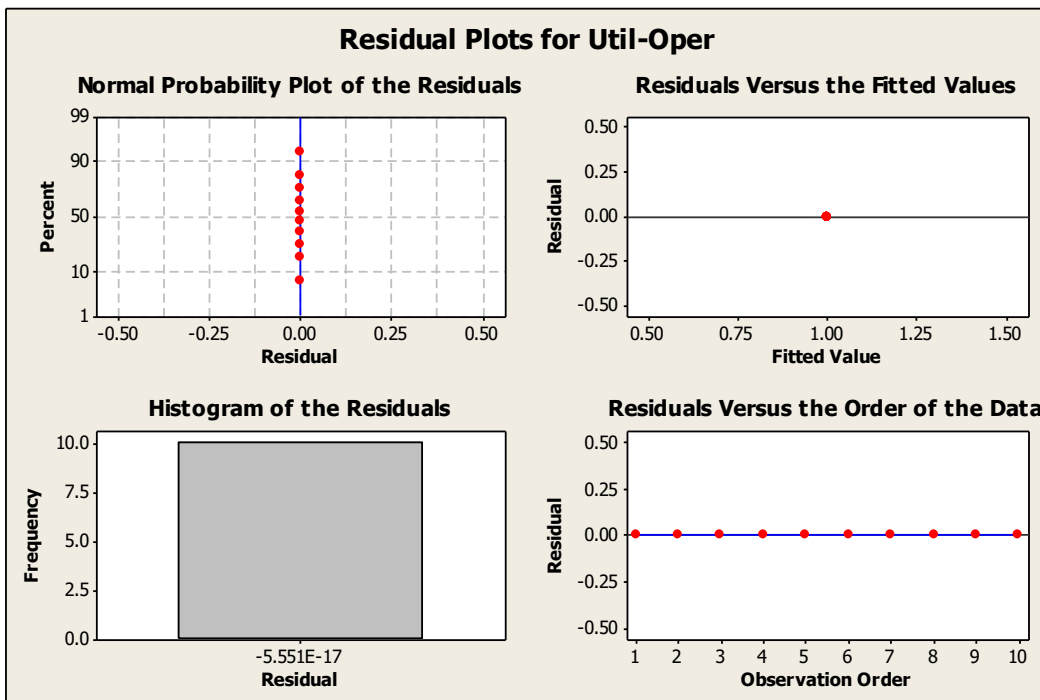
Run	Util-Oper	Util-Oper (Model)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
6	1	1
7	1	1
8	1	1
9	1	1
10	1	1

Charts of the mean:





Residual Plots:



There is no difference between the actual value and the estimated value from the regression equation. The utilization of operators equals to 1 in all the runs.

Conclusion:

There is no regression for the utilization of operators. We concluded that these factors have no effect with the utilization of operators.

Utilization of Machine:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Util-Mach	10	10	0	10	0.028	0.031

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	4 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 2

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

$$\text{Util-Mach} = - 0.694 + 0.117 \text{ Operator} + 0.0992 \text{ Machine} - 0.0167 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	-0.6943	0.1240	-5.60	0.001
Operator	0.11733	0.01980	5.93	0.001
Machine	0.09925	0.03368	2.95	0.026
interact	-0.016750	0.005421	-3.09	0.021

Analysis of Variance for Util-Mach, using Adjusted SS for Tests

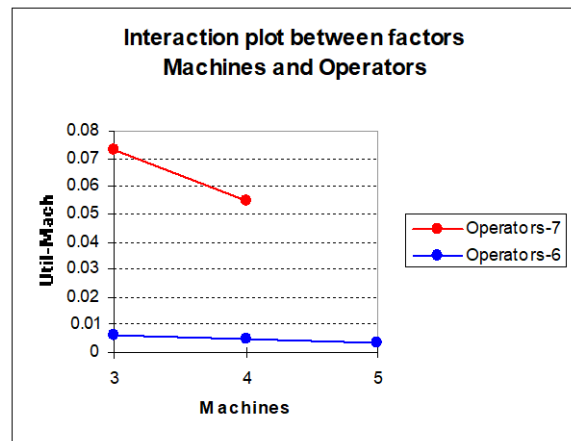
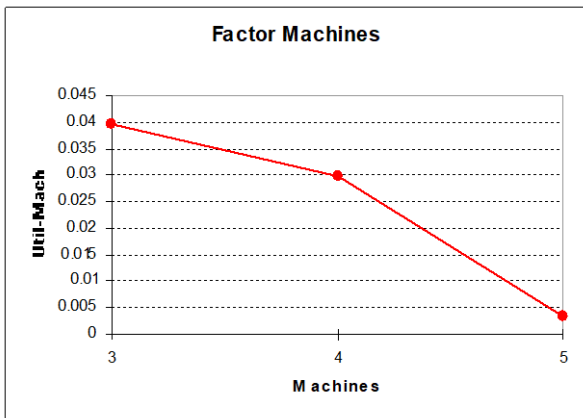
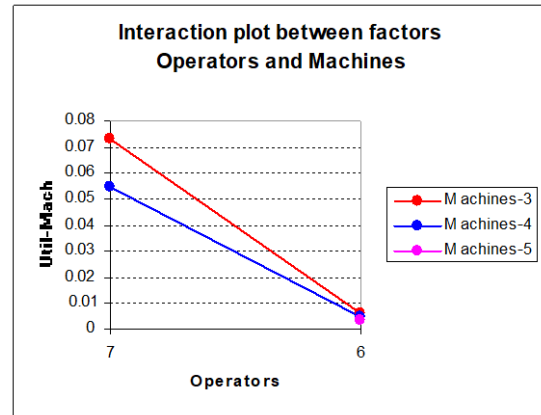
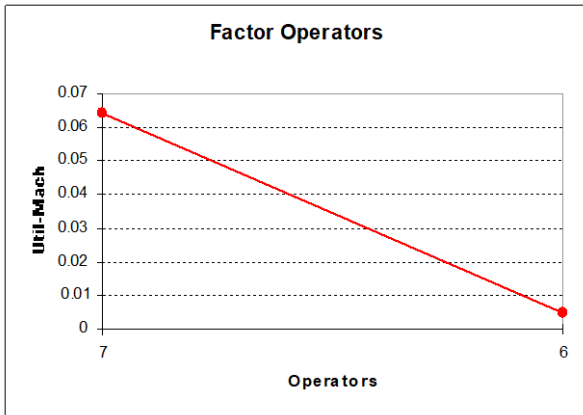
Source	Model DF	Reduced DF	Seq SS	MS	F	P
Operator	1	1	0.0084491	0.0084491	299.613	0.00001
Machine	2	2	0.0001942	0.0000971	3.443	0.115
Operator*Machine	2	1+	0.0001361	0.0001361	4.826	0.07941
Error	4	5	0.0001410	0.0000282		
Total	9	9	0.0089204			

S = 0.00531037 R-Sq = 98.42% R-Sq(adj) = 97.15%

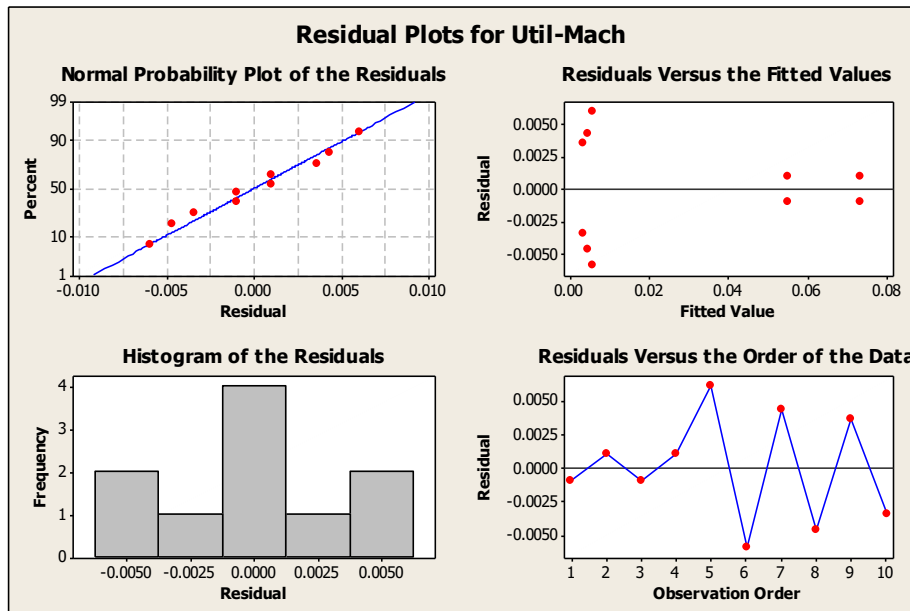
Estimated Values:

Run	Util-Machine	Util-Machine (Model)
1	0.072	0.0719
2	0.074	0.0719
3	0.054	0.0542
4	0.056	0.0542
5	0.012	0.005
6	0	0.005
7	0.009	0.004
8	0	0.004
9	0.007	0.003
10	0	0.003

Charts of the means:



Residual Plots:



The difference between the actual values and the values predicted by the regression equation is looked like a normal distribution. The normal plot of residuals is close to linear. The residuals between Run1 to Run4 are close. On the other hand, the residuals between Run5 to Run10 are quite different.

Conclusion:

From the ANOVA model, the operators, the machines factor, and interaction factor between operators and machines have some effects with the utilization of the machines.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is significant ($F=4.826, p=0.07941$). This indicates that the effect of Operators doesn't depend on the level of Machines and vice versa. The test for the operator effect is valid, showing a significant Operators effect ($F=299.613, p=0.00001$). On the other hand, the test for the machine effect isn't valid, showing no significant Machines effect ($F=3.443, p=0.115$).

We concluded that only the operator has a significant effect to the utilization of machines.

Correlations: Util-Clerk, Util-Oper, Util-Mach, Tsys

	Util-Clerk	Util-Oper	Util-Mach
Util-Oper	*		
	*		
Util-Mach	0.967	*	
	0.000	*	
Tsys	0.633	*	0.483
	0.049	*	0.158

Cell Contents: Pearson correlation
P-Value

There is no correlation between the utilization of Operators and the other responses. The utilization of Machines has correlation with the utilization of the utilization of clerk. And the times in the system has correlation with all the utilizations except the utilization of Operators.

Prediction and Interval Estimation (for Operator = 5; and Machines = 4)

Response	Estimated Values	Upper bound 95%	Lower bound 95%
Times in the system	7167	8357.286	5976.714
Utilization of Clerk	-0.0085 ~ 0	0.0205	-0.0375 ~ 0
Utilization of Operators	1	1	1
Utilization of Machines	-0.0462 ~ 0	-0.0362 ~ 0	-0.0562 ~ 0

Assumption: The fewer operators are used, the less the times in the system, the utilization of clerk and machines is. Operators and machines are not the factors of the utilization of operators. We are 95% confident that the estimated values for 5 operators and 4 machines are within the interval in the above table.

II.)

The Data (Adding 2 more runs to balance ANOVA)

Run	Operator	Machine	Tsys	Util of clerk	Util of operators	Util of machines
1	7	3	7967	0.141	1	0.072
2	7	3	7926	0.143	1	0.074
3	7	4	7967	0.141	1	0.054
4	7	4	7926	0.143	1	0.056
5	7	5	7967	0.141	1	0.043
6	7	5	7026	0.143	1	0.045
7	6	3	8154	0.081	1	0.012
8	6	3	6959	0.052	1	0
9	6	4	8154	0.081	1	0.009
10	6	4	6959	0.052	1	0
11	6	5	8154	0.081	1	0.007
12	6	5	6959	0.052	1	0

Interpretation of Output

Oper	Mach	Mean-Tsys	Std. Dev-Tsys	Mean-UtilC	Std. Dev-Clerk	Mean-UtilO	Std. Dev-O	Mean-UtilM	Std. Dev-M	N
7	3	7946.5	28.99	0.142	0.0014	1	0	0.073	0.0014	2
	4	7946.5	28.99	0.142	0.0014	1	0	0.055	0.0014	2
	5	7946.5	28.99	0.142	0.0014	1	0	0.044	0.0014	2
	Total	7946.5	22.47	0.142	0.0011	1	0	0.057	0.013	6
6	3	7556.5	844.993	0.0665	0.0205	1	0	0.006	0.008485281	2
	4	7556.5	844.993	0.0665	0.0205	1	0	0.0045	0.006363961	2
	5	7556.5	844.993	0.0665	0.0205	1	0	0.0035	0.004949747	2
	Total	7556.5	654.53	0.0665	0.016	1	0	0.0047	0.005354	6
Total	3	7751.5	537.57	0.10425	0.0135	1	0	0.0395	0.039	4
	4	7751.5	537.57	0.10425	0.0135	1	0	0.02975	0.029	4
	5	7751.5	537.57	0.10425	0.045	1	0	0.02375	0.0236	4
	Total	7751.5	486.25	0.10425	0.0409	1	0	0.031	0.029	12

An analysis of these means reveals that for mean times in the system, there is no difference between the marginal means of machines across the levels of operator. The marginal means of operator over levels machine are different (7946.5 vs. 7556.5) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased.

For utilization of the clerk, there is no difference between the marginal means of machines across the levels of operator. The marginal means of operator over levels machine are different (0.142 vs. 0.0665) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased.

For utilization of the operators, there is no difference between the marginal means across the levels of operator. Same as the marginal means of operator over levels machine which is no difference.

For utilization of the machines, there are different between the marginal means of machines across the levels of operator (0.0395 vs. 0.02975 vs. 0.02375). The marginal means of operator over levels machine are also different (0.057 vs. 0.0047) with the 7-operator mean being higher. The cell means show a decreasing pattern for levels of operator decreased as well.

ANOVA Model

Times in the System:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Tsys	12	12	0	12	7751.5	486.25

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	6 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 4

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

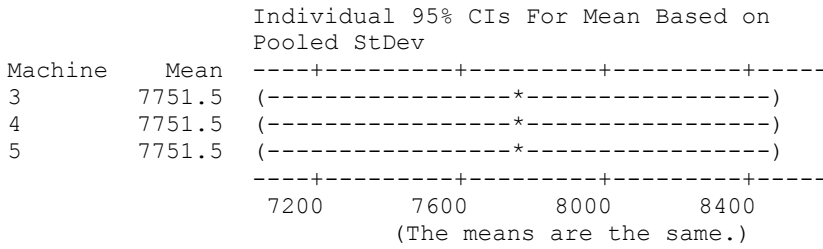
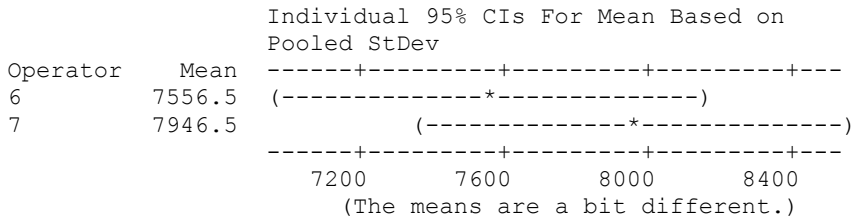
$$Tsys = 5217 + 390 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	5217	9744	0.54	0.607
Operator	390	1495	0.26	0.801
Machine	-0	2387	-0.00	1.000
interact	0.0	366.1	0.00	1.000

Two-way ANOVA: Tsys versus Operator, Machine

Source	DF	SS	MS	F	P
Operator	1	456300	456300	1.28	0.302
Machine	2	0	0	0.00	1.000
Interaction	2	0	0	0.00	1.000
Error	6	2144559	357427		
Total	11	2600859			

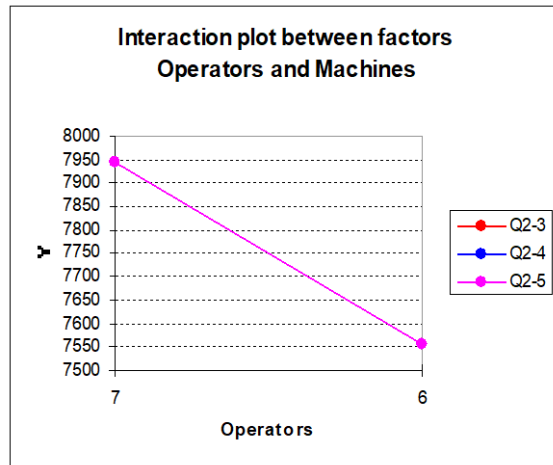
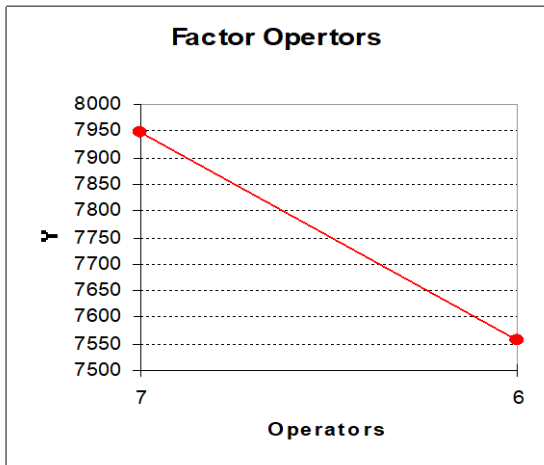
s = 597.9 R-Sq = 17.54% R-Sq(adj) = 0.00%

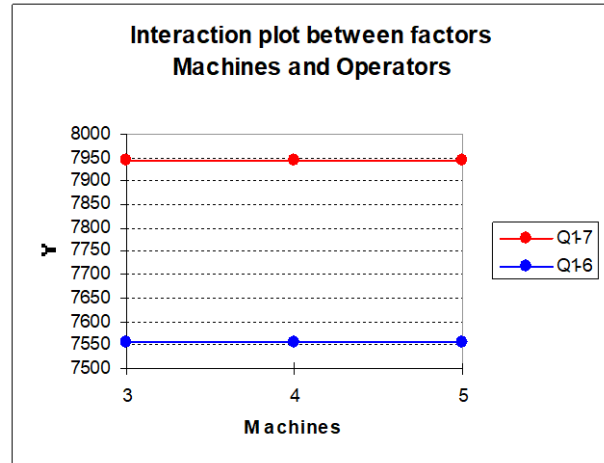
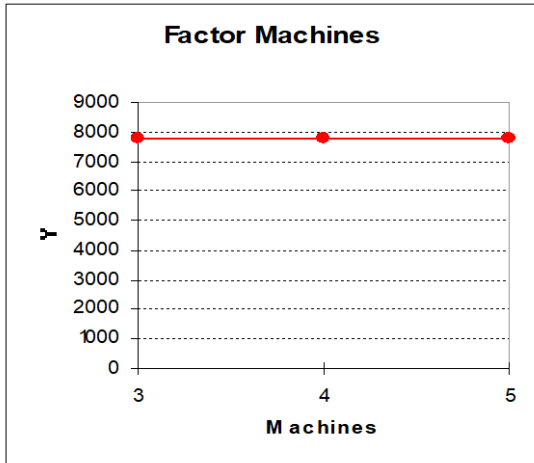


Estimated Values:

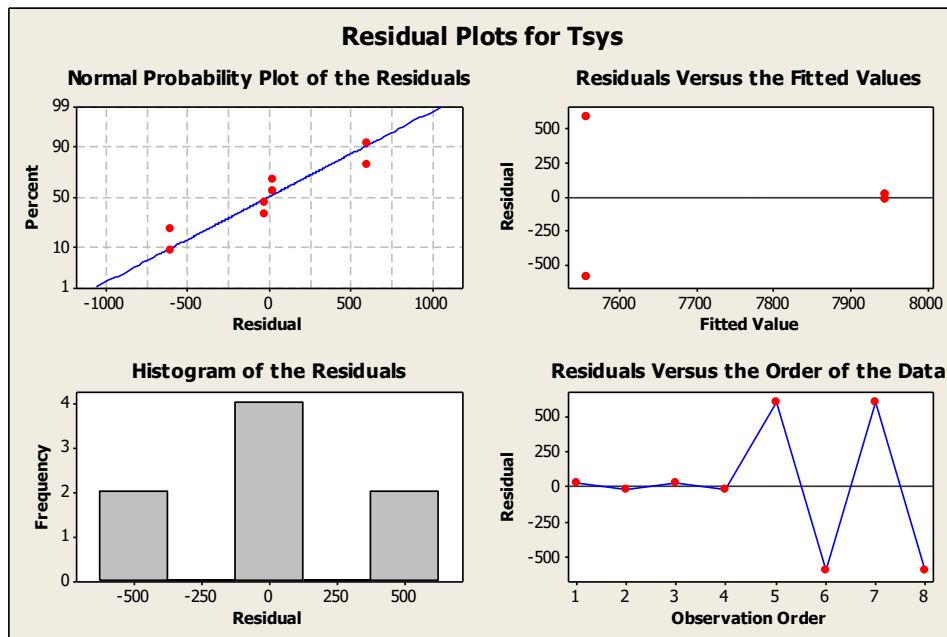
Run	Tsys	Tsys (Model)
1	7967	7947
2	7926	7947
3	7967	7947
4	7926	7947
5	7967	7947
6	7926	7947
7	8154	7557
8	6959	7557
9	8154	7557
10	6959	7557
11	8154	7557
12	6959	7557

Charts of the means:





Residual Plots:



The difference between the actual values and the values predicted by the regression equation can be divided in 3 groups; -500, 0, and 500. Run1 to Run4 don't have much difference between the actual values and estimated values since the residuals are around zero.

Conclusion:

From the ANOVA model, the machines factor and interaction factor between operators and machines have no effect with the mean times in the system.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is not significant ($F=0, p=1$). This indicates that the effect of Operators does not depend on the level of Machines and vice versa. Therefore, the tests for the individual

effects aren't valid, showing no significant Operators effect ($F=1.28$), $p=0.302$) and also no significant Machines effect ($F=0$, $p=1$).

We concluded that operators, machines, and their interaction have no significant effect to times in the system.

Utilization of Clerk:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Util-Clerk	12	12	0	12	0.10425	0.0409

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	6 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 4

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

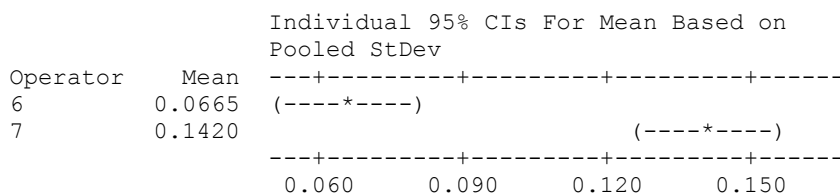
$$\text{Util-Clerk} = - 0.386 + 0.0755 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	-0.3865	0.2369	-1.63	0.141
Operator	0.07550	0.03634	2.08	0.071
Machine	-0.00000	0.05802	-0.00	1.000
interact	0.000000	0.008900	0.00	1.000

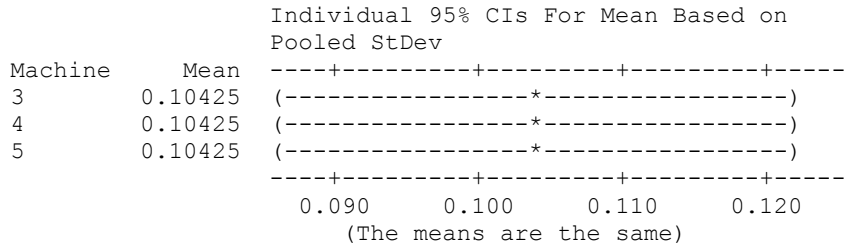
Two-way ANOVA: Util-Clerk versus Operator, Machine

Source	DF	SS	MS	F	P
Operator	1	0.0171007	0.0171007	80.95	0.000
Machine	2	0.0000000	0.0000000	0.00	1.000
Interaction	2	0.0000000	0.0000000	0.00	1.000
Error	6	0.0012675	0.0002113		
Total	11	0.0183683			

S = 0.01453 R-Sq = 93.10% R-Sq(adj) = 87.35%



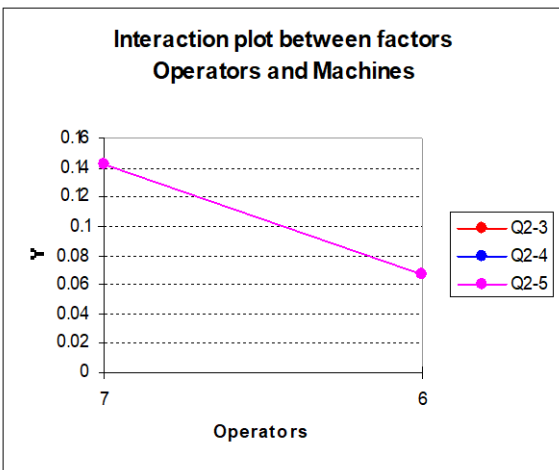
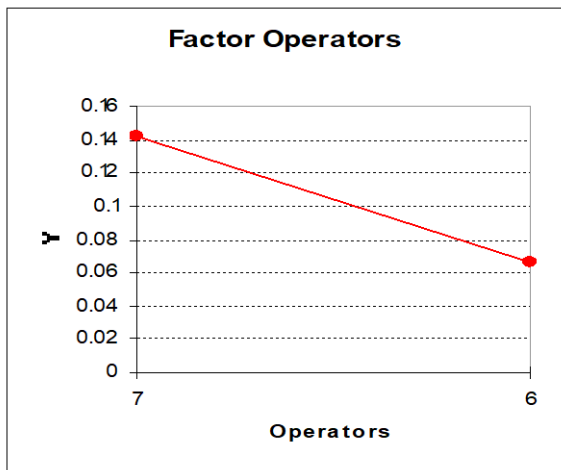
(The means are obviously different.)

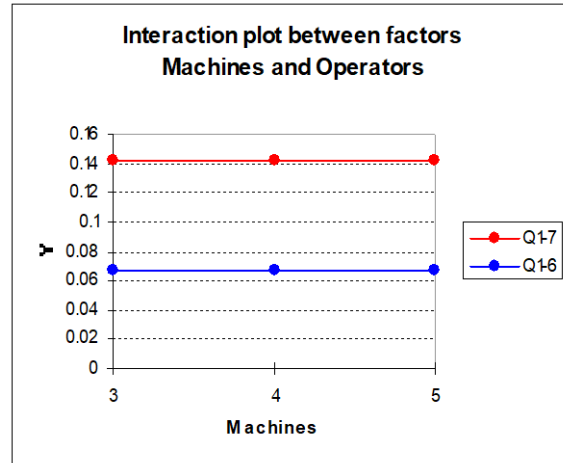
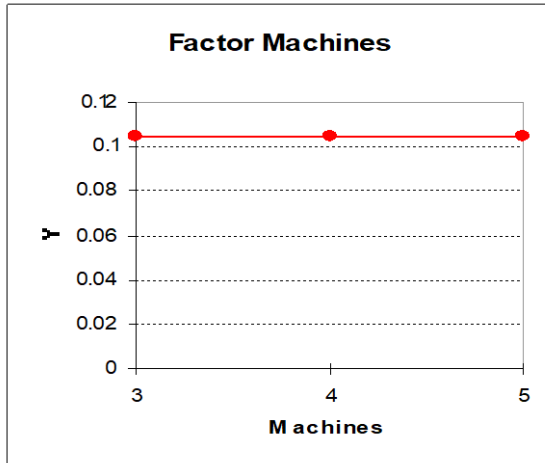


Estimated Values:

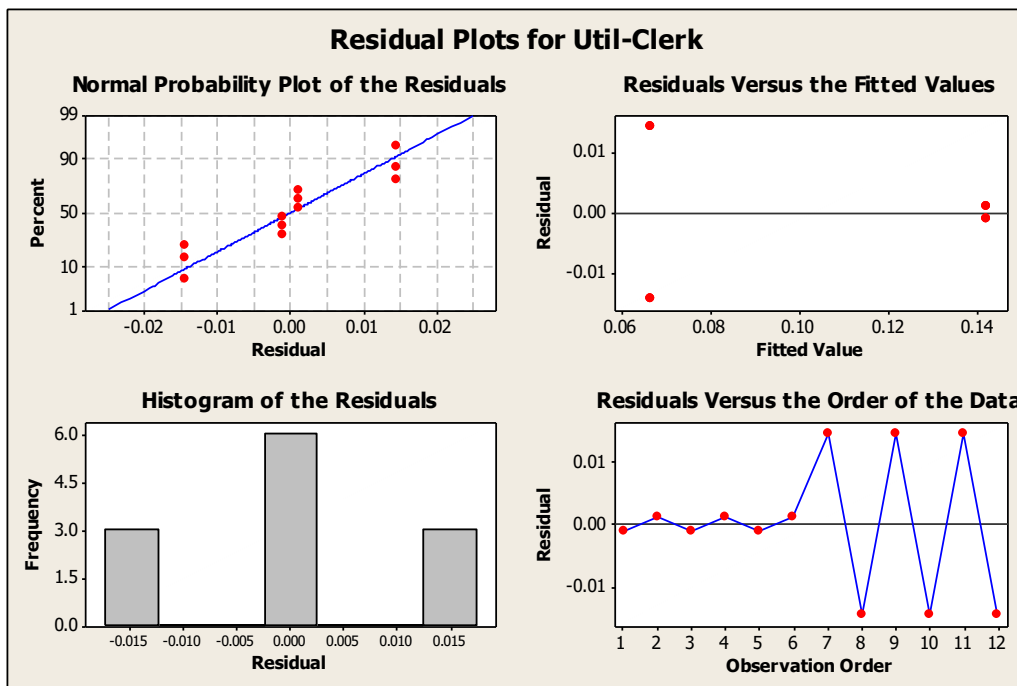
Run	Util-Clerk	Util-Clerk (Model)
1	0.141	0.1425
2	0.143	0.1425
3	0.141	0.1425
4	0.143	0.1425
5	0.141	0.1425
6	0.143	0.1425
7	0.081	0.067
8	0.052	0.067
9	0.081	0.067
10	0.052	0.067
11	0.081	0.067
12	0.052	0.067

Charts of the means:





Residual Plots:



The difference between the actual values and the values predicted by the regression equation can be divided in 3 groups; -0.015, 0, and 0.015. Run1 to Run4 don't have much difference between the actual values and estimated values since the residuals are around zero.

Conclusion:

Same as the conclusion of times in the system by analyzing the ANOVA model, the machines factor and interaction factor between operators and machines have no effect with the utilization of the clerk.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is not significant ($F=0, p=1$). This indicates that the effect of Operators does not

depend on the level of Machines and vice versa. The test for the operator effect is valid, showing a significant Operators effect ($F=80.95, p=0$). On the other hand, the test for the machine effect isn't valid, showing no significant Machines effect ($F=0, p=1$).

We concluded that only operator has a significant effect to the utilization of clerk.

Utilization of Operator:

Summary for the dependent variable:

Variable	Total no. of values	No. of values used	No. of values ignored	Sum of weights	Mean	Standard deviation
Util-Oper	12	12	0	12	1	0

Summary for the qualitative variables:

Variable	Number of categories	Categories	Frequencies
Operators	2	7 ~ 6	6 ~ 6
Machines	3	3 ~ 4 ~ 5	4 ~ 4 ~ 4

Factor	Type	Levels	Values
Operator	fixed	2	6, 7
Machine	fixed	3	3, 4, 5

ANOVA Model:

$$\text{Util-Oper} = 1 - 0 \text{ Operator} - 0 \text{ Machine} + 0 \text{ interact}$$

Predictor	Coef	SE Coef	T	P
Constant	1.00000	0.00000	*	*
Operator	-0.00000000	0.00000000	*	*
Machine	-0.00000000	0.00000000	*	*
interact	0.00000000	0.00000000	*	*

Two-way ANOVA: Util-Oper versus Operator, Machine

Source	DF	SS	MS	F	P
Operator	1	0	0	*	*
Machine	2	0	0	*	*
Interaction	2	0	0	*	*
Error	6	0	0		
Total	11	0			

S = 0 R-Sq = *% R-Sq(adj) = *%

Individual 95% CIs For Mean Based on Pooled StDev

Operator	Mean	CI Lower	CI Upper
6	1	*	*
7	1	*	*

1.00000 1.00010 1.00020 1.00030
(The means are the same.)

Individual 95% CIs For Mean Based on Pooled StDev

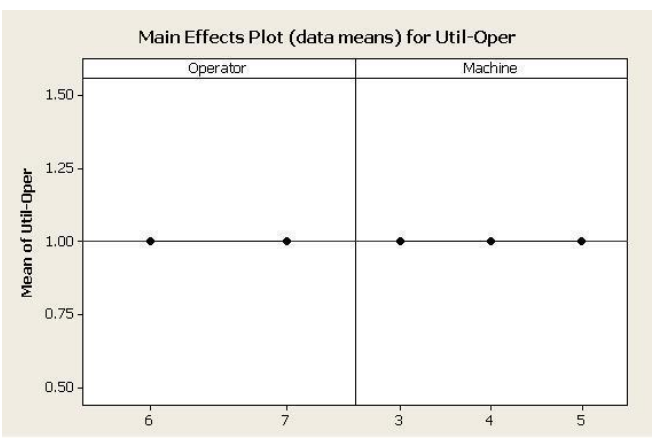
Machine	Mean	CI Lower	CI Upper
3	1	*	*
4	1	*	*
5	1	*	*

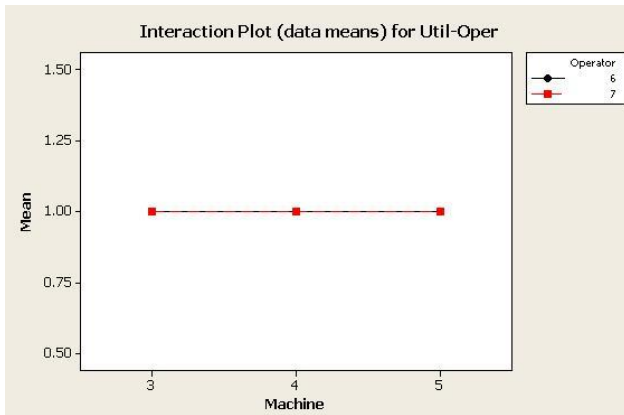
1.00000 1.00010 1.00020 1.00030
(The means are the same.)

Estimated Values:

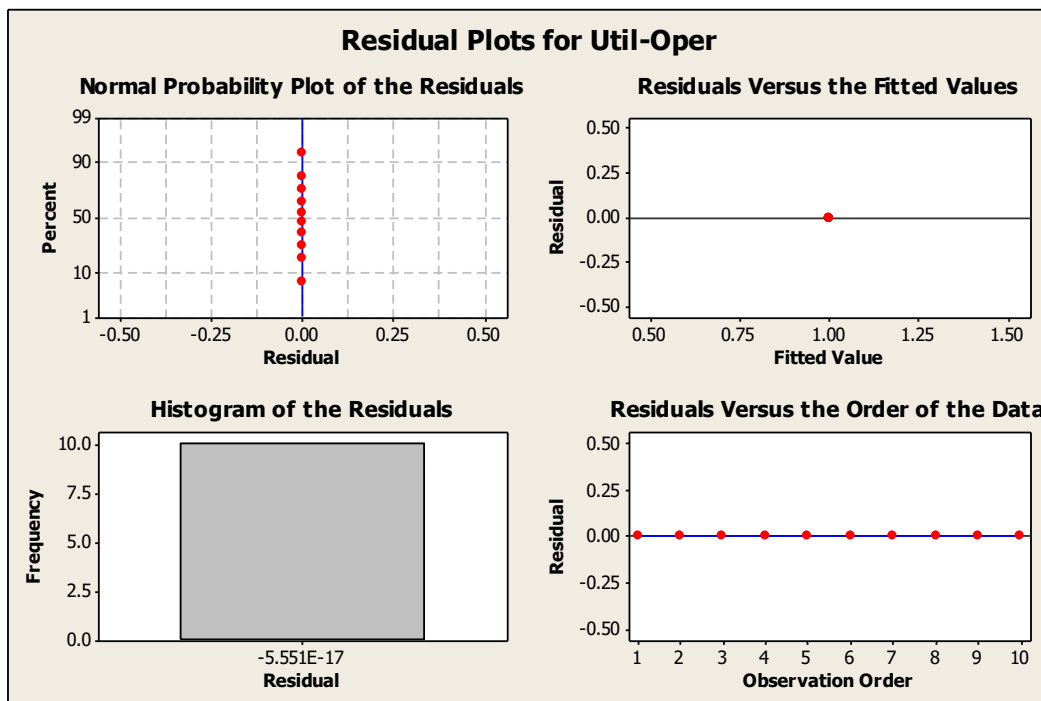
Run	Util-Oper	Util-Oper (Model)
1	1	1
2	1	1
3	1	1
4	1	1
5	1	1
6	1	1
7	1	1
8	1	1
9	1	1
10	1	1
11	1	1
12	1	1

Charts of the mean:





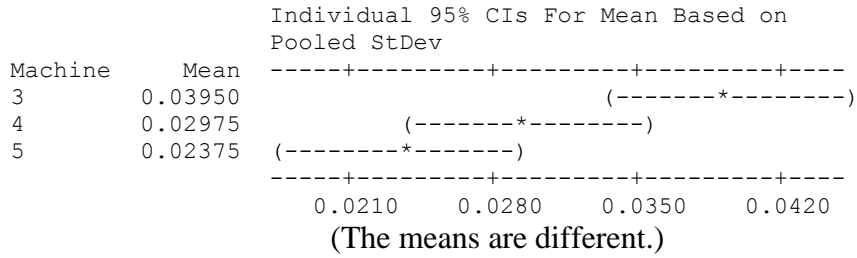
Residual Plots:



There is no difference between the actual value and the estimated value from the regression equation. The utilization of operators equals to 1 in all the runs.

Conclusion:

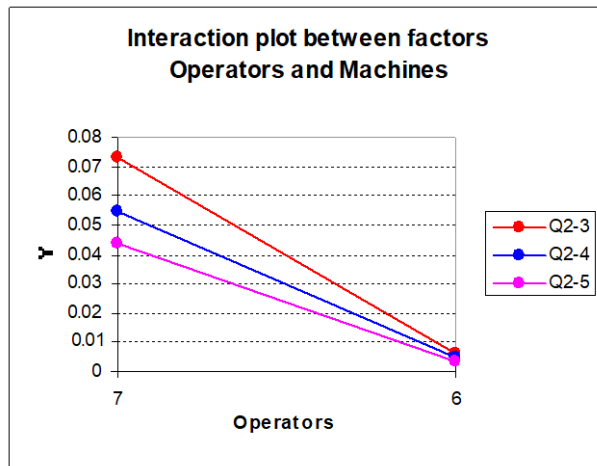
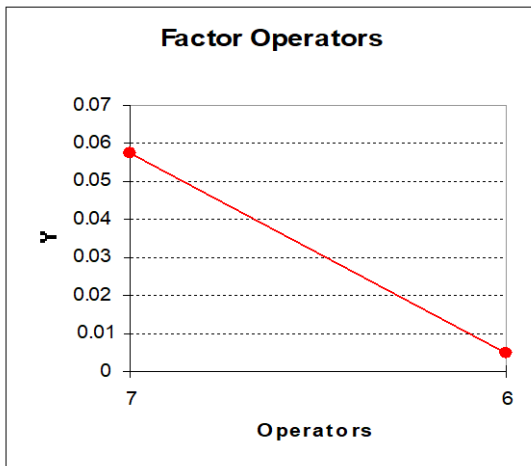
There is no regression for the utilization of operators. We concluded that these factors have no effect with the utilization of operators.

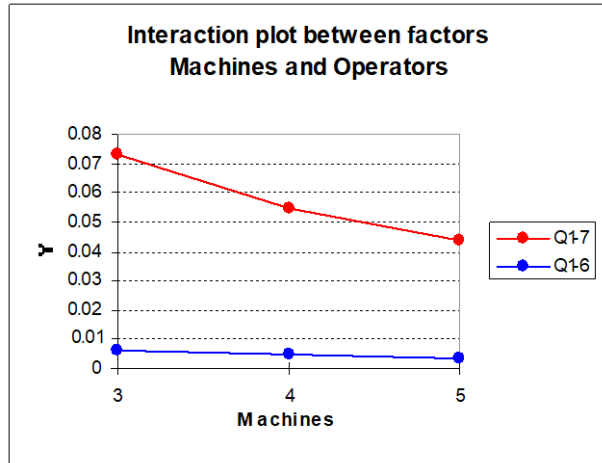
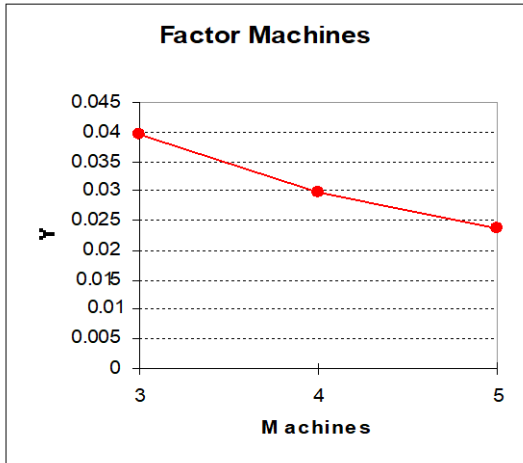


Estimated Values:

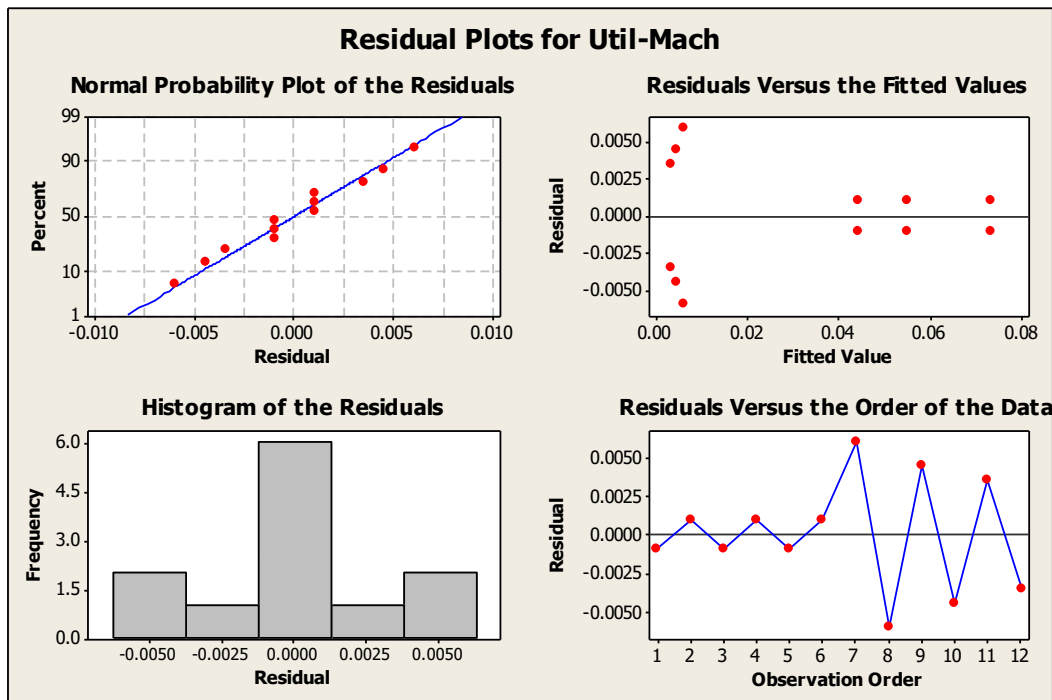
Run	Util-Machine	Util-Machine (Model)
1	0.072	0.0754
2	0.074	0.0754
3	0.054	0.0612
4	0.056	0.0612
5	0.043	0.047
6	0.045	0.047
7	0.012	0.009
8	0	0.009
9	0.009	0.008
10	0	0.008
11	0.007	0.007
12	0	0.007

Charts of the means:





Residual Plots:



The difference between the actual values and the values predicted by the regression equation is looked like a normal distribution. The normal plot of residuals is close to linear. The residuals between Run1 to Run4 are close. On the other hand, the residuals between Run5 to Run10 are quite different.

Conclusion:

From the ANOVA model, the operators, the machines factor, and interaction factor between operators and machines have some effects with the utilization of the machines.

According to a significance level of 5% ($\alpha=0.05$), the Operators*Machines interaction is significant ($F=7.51, p=0.023$). This indicates that the effect of Operators depends on the level of Machines and vice versa. Therefore, the tests for the individual effects are valid, showing a significant Operators effect ($F=349.15, p=0$), and also showing a significant Machines effect ($F=10.6, p=0.011$).

We concluded that the operators, machines, and their interaction have significant effect to the utilization of machines.

Correlations: Util-Clerk, Util-Oper, Util-Mach, Tsys

	Util-Clerk	Util-Oper	Util-Mach
Util-Oper	*		
	*		
Util-Mach	0.943	*	
	0.000	*	
Tsys	0.641	*	0.502
	0.025	*	0.096

Cell Contents: Pearson correlation
P-Value

There is no correlation between the utilization of Operators and the other responses. The utilization of Machines has correlation with the utilization of the utilization of clerk. And the times in the system has correlation with all the utilizations except the utilization of Operators.

Prediction and Interval Estimation (for Operator = 5; and Machines = 4)

Response	Estimated Value	Upper bound 95%	Lower bound 95%
Times in the system	7167	8201.705	6132.295
Utilization of Clerk	-0.0085 ~ 0	0.0165	-0.0335 ~ 0
Utilization of Operators	1	1	1
Utilization of Machines	-0.0452 ~ 0	-0.0372 ~ 0	-0.0532 ~ 0

Assumption: The fewer operators are used, the less the times in the system, the utilization of clerk and machines is. Operators and machines are not the factors of the utilization of operators. We are 95% confident that the estimated values for 5 operators and 4 machines are within the interval in the above table.

Compare between I and II analysis

The different between the unbalanced test and adding 2 more runs appears in the analysis of the utilization of machines. The operator is the only factor in the unbalanced test, but the operator, machine, and their interaction are all the factors of the utilization of machines. For the other responses, the analysis results are close. Their conclusions are the same, including the correlation.

Recommendation To the Owner

From the data provided and the analysis of that data we conclude the following;

Time In the System

From the ANOVA Test we found that there were no interaction factors between the number of Operators and Machines that have an effect on the mean Time in the System. From the estimated models, we concluded that utilizing 6 Operators in lieu of 7 Operators, the Time in the system was reduced by approx. 400 units. The actual data provided an even greater reduction in time for the respective Operators.

Clerks

From the ANOVA Test we found that there were no interaction factors between the number of Operators and Machines that have an effect on the Utilization of the Clerk. From the data we noticed a trend, as we decreased the number of Operators the Utilization of the Clerks dropped considerably. When we had 7 Operators the utilization remained constant at 14%, but when we reduced the number of Operators to 6, we obtained a utilization that varied between 5% and 8%. The data tends to indicate that the number of machines had no effect.

Operators

The Utilization of Operators remained constant at 100% across the test.

Machines

From the ANOVA Test we found that there were some interaction factors between the number of Operators and Machines that have an effect on the Utilization of the Machines. The greatest utilization of the machines appears to be with 7 Operators and 3 Machines. With this configuration, the data indicated 72% utilization. When the number of machines increased and Operators remained at 7, we saw a steady 20% decline in utilization. When we reduced the number of Operators to 6, we saw a complete shift in utilization, which dropped to below 1%.

Prediction Interval

The Prediction Interval indicated the same trends. As we reduced the number of operators and increased the number of machines our utilization of the clerk dropped to less than 1%, utilization of the operators remained at 100% and the utilization of the Machines dropped to less than 1%. The data indicates that as we reduce the number of operators and increase the number of machines the Clerks have less work to do, the operators do remain busy, but we have more machines remaining idle, waiting for work to arrive.

Final Conclusion

In order to optimize production and reduce cost we recommend the following; hire 7 Operators, and buy 3 machines. With this configuration, the Clerk will be utilized to their maximum potential of 14%, the Operators will remain utilized at 100% and the machines will be utilized at 73%. This configuration has additional benefits too. The company will

not have to purchase additional machinery, the additional machinery will not be taking up floor space that can be utilized for other functions and the overall floor space may be reduced that will reduce the overall monthly overhead costs. This configuration should maximize the company's profits.