

APPENDIX 1

**PROCESS ROUTING AND TIMES IN THE PROPOSED SIMULATION MODEL
(BASELINE MODEL)**

Product	Sequence	Location	Distr. name	Timing (min)		Distr. name	Timing (min)	
				Average	SD		Set-up	SD
A	1	WC1	dnd time 1~1	12	0.56	dnd set up WC1	21	1.7
A	2	WC4	dnd time 1~4	9	0.58	dnd set up WC4	26	2.3
A	3	WC5	dnd time 1~5	8	0.83	dnd set up WC5	25	4.6
A	4	WC9	dnd time 1~9	13	0.88	dnd set up WC9	22	1.9
A	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A
B	1	WC2	dnd time 2~2	22	0.95	dnd set up WC2	23	5
B	2	WC6	dnd time 2~6	11	0.67	dnd set up WC6	29	3.9
B	3	WC7	dnd time 2~7	13	0.57	dnd set up WC7	28	3.4
B	4	WC9	dnd time 2~9	10	0.46	dnd set up WC9	22	1.9
B	5	Shipping	dnd shipping	12	N/A		N/A	N/A
C	1	WC3	dnd time 3~3	25	0.99	dnd set up WC3	20	2.9
C	2	WC4	dnd time 3~4	7	0.57	dnd set up WC4	26	2.3
C	3	WC6	dnd time 3~6	13	0.76	dnd set up WC6	29	3.9
C	4	WC7	dnd time 3~7	8	0.86	dnd set up WC7	28	3.4
C	5	Shipping	dnd shipping	12	N/A		N/A	N/A
D	1	WC1	dnd time 4~1	14	0.53	dnd set up WC1	21	1.7
D	2	WC5	dnd time 4~5	9	0.94	dnd set up WC5	25	4.6
D	3	WC8	dnd time 4~8	7	0.82	dnd set up WC8	27	2.8
D	4	WC9	dnd time 4~9	14	0.69	dnd set up WC9	22	1.9
D	5	Shipping	dnd shipping	12	N/A		N/A	N/A
E	1	WC2	dnd time 5~2	19	0.78	dnd set up WC2	23	5
E	2	WC5	dnd time 5~5	9	0.83	dnd set up WC5	25	4.6
E	3	WC6	dnd time 5~6	15	0.92	dnd set up WC6	29	3.9
E	4	WC8	dnd time 5~8	9	0.85	dnd set up WC8	27	2.8
E	5	Shipping	dnd shipping	12	N/A		N/A	N/A

APPENDIX 1 (continued)

WORK CENTRE / MACHINE PARAMETERS

Work centre	Efficiency	Avg. Repair time (min)	Usage cost per minute	Input/output buffer	
				Capacity	*Cost
1	93%	23	\$0.15	10	\$0.01
2	91%	26	\$0.19	10	\$0.01
3	94%	30	\$0.10	10	\$0.01
4	88%	28	\$0.13	10	\$0.01
5	83%	29	\$0.11	10	\$0.01
6	96%	27	\$0.14	10	\$0.01
7	89%	20	\$0.16	10	\$0.01
8	85%	30	\$0.10	10	\$0.01
9	88%	21	\$0.17	10	\$0.01

* Cost per item per minute

OPERATOR PARAMETERS

Operator	Allocated machines	Cost per minute	Availability %	Average absence time
1	WC1	\$0.16	96%	530 min
2	WC2	\$0.16	96%	600 min
3	WC3, WC4	\$0.21	97%	495 min
4	WC5, WC7, WC8	\$0.21	97%	480 min
5	WC6	\$0.16	96%	510 min
6	WC9	\$0.16	96%	550 min

APPENDIX 1 (continued)

AUTOMATED GUIDED VEHICLE PARAMETERS

Loading/unloading capacity		Speed	Timing (minutes)	
Minimum	Maximum		Loading	Unloading
1	10	5	1.2	1.2

PRODUCT MIX PARAMETERS

PRODUCT	PROPORTION
A	23%
B	17%
C	20%
D	18%
E	22%

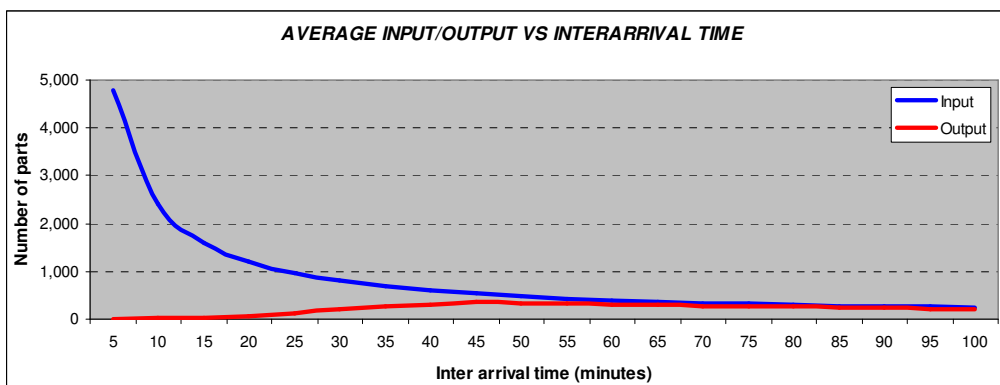
RAW MATERIAL AND FINISHED PRODUCT PARAMETERS

Raw material Cost per unit	Finished product Revenue per unit
\$20	\$130

APPENDIX 2

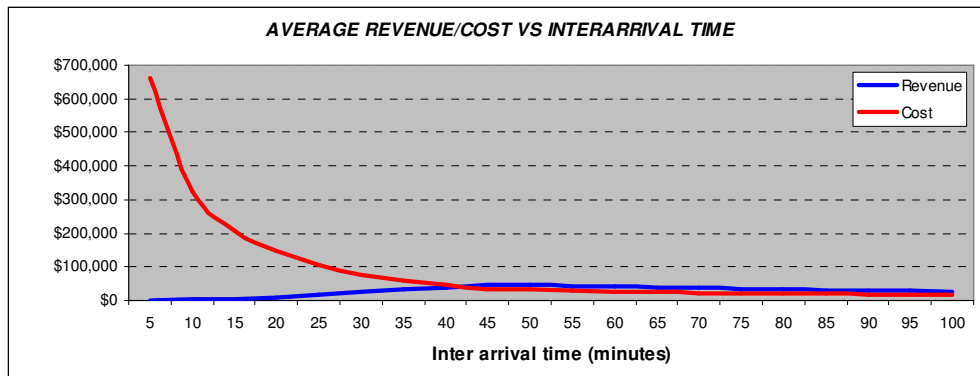
DETERMINATION OF INTERARRIVAL TIME

Once the distributions concerning the timing of machines and availability of operators were defined, the following step was to determine a suitable interarrival time to replicate the arrival of material into the simulation model. At this point in model building stage, it is very important to have made all the necessary considerations before determining an interarrival time. Assuring that all the components and their associated parameters have been considered would generate a reliable reference data avoiding unnecessary repetitions caused by omissions of specific details. Before selecting an interarrival time, it had been already determined that the exponential distribution is a proper distribution for representing independent arrivals into the system. To determine a suitable interarrival time, a series of incremental interarrival times was entered into the model and their correspondent model performance was analyzed. The tested sequence started with an interarrival time of 5 minutes which was sequentially incremented in 5 minutes steps up to 100 minutes. 30 replication of a 400 hour simulation run were conducted so to obtain the average of each outcome. System performance in terms of throughput, manufacturing costs, and time was the primary criterion to select the most suitable interarrival time. See the results below.

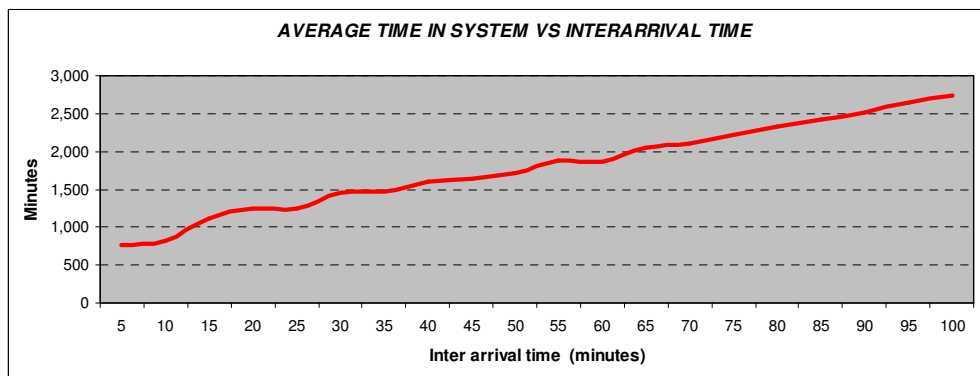


The figure above shows the input and output of the model at different interarrival times. The distance between the input line and the output line is the work-in-process inventory (WIP). Note the accumulation of WIP at low interarrival times caused by the model becoming blocked as its capacity to process parts is exceeded by the elevated number of parts arriving into the system. From the same figure it can be noticed that in order to avoid frequent model blocking caused by an excess of parts entering into the system the difference between input and output must not be high, therefore an interarrival from 40 minutes upwards should be chosen. The figure below shows the average revenue and cost versus the series of interarrivals. Note the high costs caused by WIP excesses at low interarrival times. The same figure indicates the point where system starts to be profitable.

APPENDIX 2 (continued)

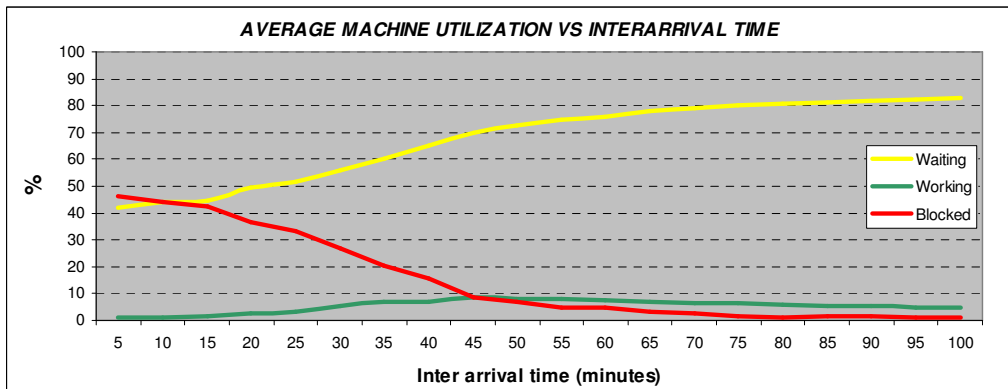


The breakeven point, as shown by the figure above, happens at an interarrival of 43 minutes. From that point upwards the system starts to generate a profit. The figure below shows the average time spent in the system at different interarrivals.

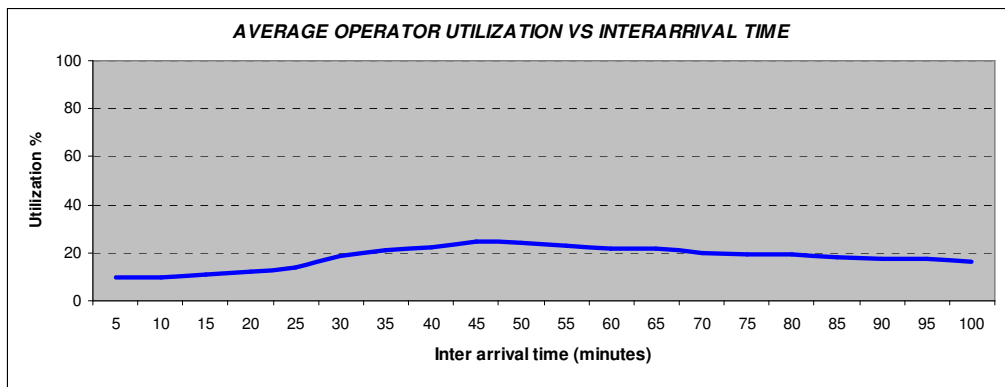


Even though the figure shows that at low interarrivals parts stay in the system for fewer minutes than at high interarrivals, this should not be misinterpreted; a low average time in the system is the result of just a few parts coming out of it due to model blocking when the number of parts arriving is excessive. The information presented by these three indicators give an idea of an adequate interarrival time; however, they do still do not provide enough information to select the most suitable interarrival time; therefore it was necessary to look at additional indicators like resources utilization. The first additional performance indication to look at was the machine utilization percentage versus arrival time figure.

APPENDIX 2 (continued)



The figure above supports what has been mentioned before with respect to the system getting blocked by excessive arrivals. It can be noticed that the average machine utilization reaches its highest point at an interarrival time of 45 minutes and after that point the utilization percentage starts a decreasing trend. Note how the machine waiting time maintains an ascending tendency along the horizontal axis.



After analyzing the operator utilization versus interarrival time figure above, an interarrival time of 45 minutes can be confidently selected after confirming that the operator utilization percentage also reaches its highest value at that interarrival time.

APPENDIX 4

SENSITIVITY ANALYSIS REPORT

The sensitivity analysis report provided by Simul8 as a built-in capability is divided into two sections:

1. The first section of the report (three first rows) corresponds to the results of a normal trial. The first line shows the lowest value for a specific model outcome. The second row shows the mean value for a specific model outcome. Similarly, the third row shows the highest value for a model outcome.
2. The second section of the sensitivity analysis report is the most important and consists of four rows for each of the tested distributions. The first row shows the trial mean with the distribution reduced by 10%. The second row shows the trial mean with the distribution increased by 10%. The third row is a measure of the sensitivity of the result to the distribution (0= not sensitive, 1= high, i.e. the 20% range moves the result between the low conf limit and the high confidence limit). Lastly, the fourth row indicates that the impact of the sensitivity test takes that result outside its confidence limits therefore model validity should be reviewed (0=within confidence limits; 1=beyond confidence limits).

The sensitivity analysis report attached in the following pages shows that none of the tested distributions have their corresponding results beyond the confidence interval therefore model assumptions are valid.

APPENDIX 4 (continued)

	TOTAL AVERAGES					
	Entered	Completed	Time in System	Revenue	Costs	Profit
Normal Trial	659.9	308.5	1306.0	40098.6	57117.6	-42541.7
	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
	674.3	466.5	1659.6	60646.2	83514.8	2654.1
dnd time 1~1: -10%	667.1	387.1	1439.7	50320.4	70522.0	-20201.6
+10%	667.1	381.1	1381.8	49548.2	72301.5	-22753.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 2~9: -10%	667.1	391.4	1470.0	50882.0	69433.1	-18551.1
+10%	667.1	387.7	1414.1	50403.6	70424.5	-20020.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 3~4: -10%	667.1	404.2	1432.5	52546.0	69608.6	-17062.6
+10%	667.1	391.0	1546.2	50835.2	68544.0	-17708.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 4~5: -10%	667.1	370.5	1452.8	48165.0	73421.8	-25256.8
+10%	667.1	398.3	1400.5	51779.0	68353.3	-16574.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 5~8: -10%	667.1	392.9	1521.5	51074.4	68443.0	-17368.6
+10%	667.1	398.2	1509.6	51760.8	67970.2	-16209.4
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 6~3: -10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
+10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 7~8: -10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
+10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 9~2: -10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
+10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 10~6: -10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
+10%	667.1	387.5	1482.8	50372.4	70316.2	-19943.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time shipping: -10%	667.1	387.5	1480.1	50372.4	70308.5	-19936.1
+10%	667.1	387.5	1486.0	50375.0	70326.3	-19951.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC4: -10%	667.1	377.1	1317.1	49020.4	73811.0	-24790.6
+10%	667.1	381.4	1402.7	49579.4	73511.0	-23931.6
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC9: -10%	667.1	391.3	1468.7	50869.0	69468.6	-18599.6
+10%	667.1	388.0	1484.3	50440.0	70246.7	-19806.7
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC3: -10%	667.1	381.0	1447.4	49530.0	72464.3	-22934.3
+10%	667.1	386.7	1434.5	50271.0	72127.1	-21856.1
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0

APPENDIX 4 (continued)

	UTILIZATION %					
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6
Normal Trial	11.1	14.7	15.2	24.2	15.5	15.1
	12.9	17.1	17.9	29.3	18.4	17.9
	14.7	19.5	20.5	34.4	21.3	20.7
dnd time 1~1: -10%	12.4	17.0	17.8	29.3	18.2	18.0
+10%	13.1	16.9	17.6	28.8	18.0	17.6
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 2~9: -10%	13.0	17.2	18.1	29.6	18.6	17.8
+10%	12.9	17.1	17.9	29.3	18.4	18.2
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 3~4: -10%	13.2	17.6	18.2	30.5	18.8	18.4
+10%	13.1	17.4	18.3	29.5	18.3	17.8
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 4~5: -10%	12.6	16.6	17.3	28.0	17.8	17.3
+10%	13.1	17.5	18.4	30.6	18.8	18.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 5~8: -10%	13.1	17.3	18.2	29.4	18.5	18.0
+10%	13.2	17.6	18.4	30.5	18.8	18.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 6~3: -10%	12.9	17.1	17.9	29.3	18.4	17.9
+10%	12.9	17.1	17.9	29.3	18.4	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 7~8: -10%	12.9	17.1	17.9	29.3	18.4	17.9
+10%	12.9	17.1	17.9	29.3	18.4	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 9~2: -10%	12.9	17.1	17.9	29.3	18.4	17.9
+10%	12.9	17.1	17.9	29.3	18.4	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time 10~6: -10%	12.9	17.1	17.9	29.3	18.4	17.9
+10%	12.9	17.1	17.9	29.3	18.4	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd time shipping: -10%	12.9	17.1	17.9	29.3	18.4	17.9
+10%	12.9	17.1	17.9	29.3	18.4	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC4: -10%	12.6	16.8	17.1	28.6	17.9	17.5
+10%	12.7	16.8	17.9	28.8	18.0	17.6
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC9: -10%	13.0	17.2	18.1	29.6	18.6	17.7
+10%	12.9	17.1	17.9	29.3	18.4	18.3
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0
dnd set up WC3: -10%	12.8	16.9	17.5	28.9	18.2	17.7
+10%	12.9	17.1	17.8	29.2	18.3	17.9
Sensitivity	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0

APPENDIX 4 (continued)

	UTILIZATION %								
	Mach 1	Mach 2	Mach 3	Mach 4	Mach 5	Mach 6	Mach 7	Mach 8	Mach 9
Normal Trial	5.9	8.9	5.8	3.7	5.7	8.1	4.0	3.3	7.4
	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
	8.6	12.9	8.2	5.5	8.5	12.2	6.0	5.1	11.2
dnd time 1~1: -10%	6.9	10.8	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.5	10.7	6.9	4.5	7.0	10.0	4.9	4.1	9.1
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 2~9: -10%	7.3	11.0	7.1	4.6	7.2	10.2	5.1	4.2	9.2
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.5
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 3~4: -10%	7.5	11.3	7.2	4.6	7.4	10.6	5.2	4.4	9.7
+10%	7.4	11.1	7.2	4.9	7.2	10.2	5.1	4.2	9.4
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 4~5: -10%	6.9	10.4	6.7	4.4	6.6	9.7	4.8	4.0	8.9
+10%	7.4	11.2	7.2	4.7	7.5	10.4	5.2	4.3	9.5
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 5~8: -10%	7.3	11.0	7.2	4.7	7.2	10.3	5.1	4.0	9.4
+10%	7.4	11.3	7.2	4.7	7.3	10.4	5.2	4.6	9.5
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 6~3: -10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 7~8: -10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 9~2: -10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time 10~6: -10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd time shipping: -10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd set up WC4: -10%	7.0	10.6	6.8	4.5	6.9	9.9	4.9	4.1	9.0
+10%	7.1	10.6	6.9	4.5	7.0	10.0	4.9	4.1	9.1
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd set up WC9: -10%	7.3	11.0	7.1	4.6	7.2	10.2	5.1	4.2	9.4
+10%	7.2	10.9	7.0	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0
dnd set up WC3: -10%	7.1	10.7	6.8	4.5	7.0	9.9	4.9	4.1	9.1
+10%	7.2	10.8	6.9	4.6	7.1	10.1	5.0	4.2	9.3
Sensitivity	0	0	0	0	0	0	0	0	0
Beyond Confidence	0	0	0	0	0	0	0	0	0

APPENDIX 5

WARM-UP PERIOD: WELCH'S METHOD

The simulation model has been replicated ten times in order to obtain a mean hourly throughput. Afterwards, 'windows' of 5, 10, and 20 periods have been considered and the equation (6.1) has been applied in each period window in order to calculate the moving averages. See table below.

Hour	Mean hourly throughput	Moving avg. window = 5	Moving avg. window =10	Moving avg. window =20
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0.3	0.01	0.01	0.0
17	0.2	0.02	0.02	0.0
18	0.3	0.04	0.04	0.0
19	0.2	0.05	0.05	0.1
20	0.3	0.12	0.12	0.1
21	0.2	0.55	0.15	0.1
22	0.5	0.60	0.19	0.2
23	1.6	0.70	0.24	0.2
24	1.1	0.75	0.32	0.3
25	0.7	0.88	0.36	0.4
26	0.6	1.08	0.94	0.4
27	0.9	1.22	0.97	0.4
28	1.3	1.26	1.03	0.5
29	0.8	1.25	1.11	0.5
30	1.7	1.25	1.18	0.6
31	2.5	1.30	1.23	0.6
32	1.7	1.33	1.30	0.6
33	1	1.39	1.37	0.7
34	1.5	1.45	1.41	0.7
35	1.1	1.53	1.41	0.8
36	1.2	1.50	1.47	1.4
37	0.9	1.41	1.55	1.5
38	1.6	1.45	1.59	1.5
39	1.9	1.57	1.63	1.6
40	1.7	1.54	1.70	1.7

APPENDIX 5 (continued)

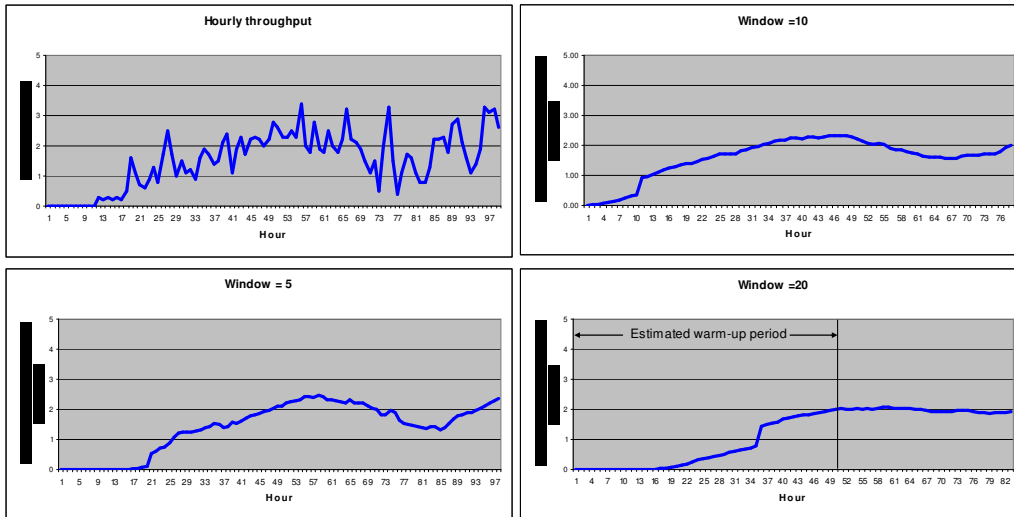
Hour	Mean hourly throughput	Moving avg. window = 5	Moving avg. window =10	Moving avg. window =20
41	1.4	1.61	1.72	1.7
42	1.5	1.71	1.70	1.7
43	2.1	1.78	1.72	1.8
44	2.4	1.84	1.81	1.8
45	1.1	1.87	1.86	1.8
46	1.9	1.92	1.92	1.9
47	2.3	1.97	1.97	1.9
48	1.7	2.04	2.05	1.9
49	2.2	2.10	2.08	1.9
50	2.3	2.12	2.15	2.0
51	2.2	2.23	2.17	2.0
52	2	2.26	2.19	2.0
53	2.2	2.28	2.25	2.0
54	2.8	2.34	2.24	2.0
55	2.6	2.45	2.21	2.0
56	2.3	2.42	2.28	2.0
57	2.3	2.38	2.28	2.0
58	2.5	2.45	2.26	2.0
59	2.3	2.43	2.28	2.1
60	3.4	2.34	2.33	2.1
61	2	2.33	2.32	2.0
62	1.8	2.30	2.32	2.0
63	2.8	2.25	2.31	2.0
64	1.9	2.23	2.28	2.0
65	1.8	2.31	2.20	2.0
66	2.5	2.20	2.15	2.0
67	2	2.21	2.06	2.0
68	1.8	2.22	2.05	1.9
69	2.2	2.10	2.09	1.9
70	3.2	2.03	2.05	1.9
71	2.2	2.00	1.90	1.9
72	2.1	1.82	1.86	1.9
73	1.9	1.82	1.86	2.0
74	1.5	1.95	1.80	2.0
75	1.1	1.89	1.76	2.0
76	1.5	1.64	1.71	1.9
77	0.5	1.54	1.63	1.9
78	2	1.50	1.60	1.9
79	3.3	1.47	1.62	1.9
80	1.5	1.44	1.62	1.9
81	0.4	1.41	1.58	1.9
82	1.1	1.35	1.56	1.9
83	1.7	1.42	1.59	1.9
84	1.6	1.44	1.63	
85	1.1	1.34	1.66	
86	0.8	1.41	1.69	
87	0.8	1.54	1.67	
88	1.3	1.68	1.71	
89	2.2	1.79	1.70	
90	2.2	1.84	1.70	

APPENDIX 5 (continued)

Hour	Mean hourly throughput	Moving avg. window = 5	Moving avg. window =10	Moving avg. window =20
91	2.3	1.88	1.78	
92	1.8	1.91	1.91	
93	2.7	1.96	1.99	
94	2.9	2.02		
95	2.1	2.12		
96	1.6	2.20		
97	1.1	2.28		
98	1.4	2.35		
99	1.9			
100	3.3			
101	3.1			
102	3.2			
103	2.6			
104	2.3			
105	1.2			
106	1.2			
107	1.3			
108	1.3			
109	1.7			
110	2.7			
111	2.8			
112	1.8			
113	3.0			
114	1.9			
115	2.0			
116	2.4			
117	3.6			
118	2.0			
119	2.5			

APPENDIX 5 (continued)

Once moving averages had been calculated for each window time-series were constructed for each moving average. See figures below.



From the different figures above it can be noticed that after a number of periods the graph becomes relatively flat, indicating that the model has reached its steady-state. The minimum warm-up time has been selected from the point at which the graph became flat, i.e. from **50 hours** simulation time.

APPENDIX 6

RUN LENGTH ESTIMATION

In order to estimate a run length of for the proposed simulation model a graphical approach has been considered. Three consecutive replications of the simulation model were performed; each replication was run during a considerable time length which included a previously estimated war-up time of 50 hours. The cumulative mean average for the throughput of the system was calculated afterwards. See the table below.

CUMMULATIVE MEAN AVERAGE FOR THROUGHPUT

RUN LENGTH	REPLICATION			RUN LENGTH	REPLICATION		
	1	2	3		1	2	3
50.00	0.00	0.00	0.00	79.00	0.78	0.64	0.58
51.00	1.00	1.00	1.00	80.00	0.77	0.64	0.58
52.00	1.00	0.67	0.67	81.00	0.77	0.65	0.57
53.00	1.00	0.50	0.60	82.00	0.76	0.66	0.58
54.00	0.88	0.71	0.56	83.00	0.75	0.68	0.59
55.00	0.84	0.73	0.57	84.00	0.74	0.67	0.59
56.00	0.87	0.75	0.55	85.00	0.73	0.67	0.59
57.00	0.85	0.71	0.58	86.00	0.73	0.67	0.61
58.00	0.81	0.67	0.57	87.00	0.72	0.67	0.60
59.00	0.79	0.68	0.59	88.00	0.71	0.67	0.60
60.00	0.81	0.65	0.61	89.00	0.71	0.67	0.59
61.00	0.79	0.66	0.59	90.00	0.71	0.67	0.58
62.00	0.81	0.68	0.58	91.00	0.71	0.66	0.58
63.00	0.83	0.69	0.56	92.00	0.71	0.66	0.57
64.00	0.82	0.68	0.55	93.00	0.69	0.65	0.58
65.00	0.81	0.64	0.54	94.00	0.69	0.65	0.58
66.00	0.79	0.65	0.52	95.00	0.69	0.66	0.58
67.00	0.78	0.63	0.51	96.00	0.69	0.67	0.59
68.00	0.76	0.62	0.50	97.00	0.68	0.68	0.58
69.00	0.75	0.60	0.52	98.00	0.68	0.68	0.58
70.00	0.77	0.61	0.51	99.00	0.68	0.67	0.57
71.00	0.77	0.60	0.56	100.00	0.69	0.67	0.58
72.00	0.77	0.59	0.59	101.00	0.70	0.67	0.59
73.00	0.78	0.61	0.62	102.00	0.71	0.67	0.59
74.00	0.78	0.62	0.63	103.00	0.72	0.67	0.59
75.00	0.78	0.62	0.62	104.00	0.73	0.67	0.60
76.00	0.78	0.64	0.61	105.00	0.73	0.67	0.59
77.00	0.77	0.64	0.60	106.00	0.73	0.66	0.59
78.00	0.77	0.64	0.59	107.00	0.72	0.66	0.59

APPENDIX 6 (continued)

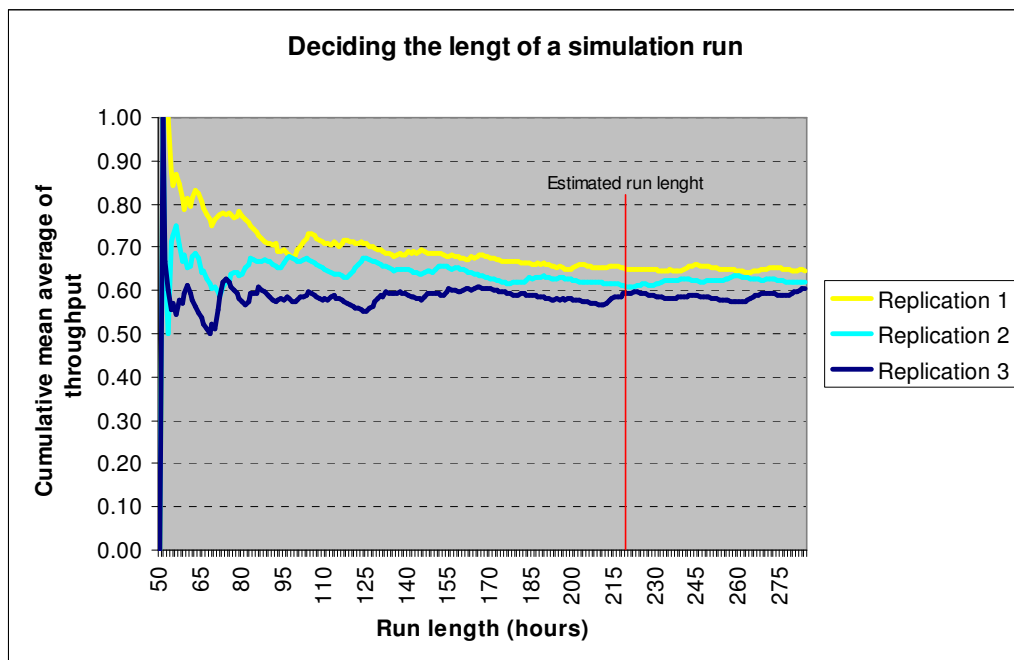
RUN LENGTH	REPLICATION			RUN LENGTH	REPLICATION		
	1	2	3		1	2	3
108.00	0.72	0.65	0.58	158.00	0.68	0.65	0.60
109.00	0.71	0.65	0.58	159.00	0.68	0.65	0.60
110.00	0.71	0.65	0.58	160.00	0.68	0.65	0.60
111.00	0.71	0.64	0.58	161.00	0.67	0.65	0.61
112.00	0.70	0.64	0.58	162.00	0.67	0.64	0.60
113.00	0.71	0.64	0.59	163.00	0.68	0.64	0.60
114.00	0.71	0.64	0.58	164.00	0.68	0.64	0.60
115.00	0.70	0.64	0.58	165.00	0.68	0.64	0.61
116.00	0.71	0.63	0.58	166.00	0.68	0.64	0.61
117.00	0.72	0.63	0.57	167.00	0.68	0.63	0.61
118.00	0.72	0.63	0.57	168.00	0.68	0.63	0.60
119.00	0.71	0.64	0.57	169.00	0.68	0.63	0.60
120.00	0.71	0.65	0.56	170.00	0.68	0.63	0.60
121.00	0.71	0.65	0.56	171.00	0.67	0.63	0.60
122.00	0.71	0.66	0.56	172.00	0.67	0.62	0.60
123.00	0.71	0.67	0.55	173.00	0.67	0.62	0.60
124.00	0.71	0.68	0.55	174.00	0.67	0.62	0.60
125.00	0.71	0.68	0.55	175.00	0.67	0.62	0.60
126.00	0.70	0.67	0.56	176.00	0.67	0.62	0.59
127.00	0.70	0.67	0.56	177.00	0.67	0.62	0.59
128.00	0.70	0.67	0.57	178.00	0.67	0.62	0.59
129.00	0.70	0.66	0.58	179.00	0.67	0.62	0.59
130.00	0.69	0.66	0.59	180.00	0.67	0.62	0.59
131.00	0.69	0.66	0.59	181.00	0.66	0.62	0.59
132.00	0.69	0.66	0.60	182.00	0.66	0.62	0.59
133.00	0.69	0.65	0.59	183.00	0.66	0.62	0.59
134.00	0.68	0.65	0.59	184.00	0.66	0.63	0.59
135.00	0.68	0.65	0.59	185.00	0.66	0.63	0.59
136.00	0.68	0.65	0.59	186.00	0.66	0.63	0.59
137.00	0.69	0.65	0.60	187.00	0.66	0.63	0.59
138.00	0.68	0.65	0.59	188.00	0.66	0.63	0.59
139.00	0.68	0.65	0.59	189.00	0.66	0.63	0.58
140.00	0.69	0.65	0.59	190.00	0.66	0.63	0.58
141.00	0.69	0.65	0.59	191.00	0.66	0.63	0.58
142.00	0.69	0.64	0.59	192.00	0.66	0.63	0.58
143.00	0.69	0.64	0.58	193.00	0.66	0.63	0.58
144.00	0.69	0.64	0.58	194.00	0.65	0.63	0.58
145.00	0.69	0.64	0.58	195.00	0.66	0.63	0.58
146.00	0.69	0.64	0.58	196.00	0.65	0.63	0.58
147.00	0.69	0.64	0.59	197.00	0.65	0.63	0.58
148.00	0.69	0.65	0.59	198.00	0.65	0.63	0.58
149.00	0.69	0.64	0.59	199.00	0.65	0.63	0.58
150.00	0.69	0.65	0.59	200.00	0.65	0.62	0.58
151.00	0.69	0.66	0.59	201.00	0.66	0.62	0.58
152.00	0.68	0.66	0.59	202.00	0.66	0.62	0.58
153.00	0.68	0.66	0.59	203.00	0.66	0.62	0.58
154.00	0.68	0.66	0.60	204.00	0.66	0.62	0.57
155.00	0.68	0.65	0.60	205.00	0.66	0.62	0.57
156.00	0.68	0.65	0.60	206.00	0.66	0.62	0.57
157.00	0.68	0.65	0.60	207.00	0.65	0.62	0.57

APPENDIX 6 (continued)

RUN LENGTH	REPLICATION			RUN LENGTH	REPLICATION		
	1	2	3		1	2	3
208.00	0.65	0.62	0.57	247.00	0.66	0.62	0.59
209.00	0.65	0.62	0.57	248.00	0.66	0.62	0.59
210.00	0.65	0.62	0.57	249.00	0.65	0.62	0.58
211.00	0.65	0.62	0.57	250.00	0.65	0.62	0.58
212.00	0.65	0.62	0.57	251.00	0.65	0.62	0.58
213.00	0.66	0.62	0.58	252.00	0.65	0.62	0.58
214.00	0.66	0.62	0.58	253.00	0.65	0.62	0.58
215.00	0.66	0.62	0.59	254.00	0.65	0.62	0.58
216.00	0.66	0.61	0.59	255.00	0.65	0.63	0.58
217.00	0.65	0.61	0.59	256.00	0.65	0.63	0.58
218.00	0.65	0.61	0.59	257.00	0.65	0.63	0.58
219.00	0.65	0.61	0.59	258.00	0.65	0.63	0.58
220.00	0.65	0.61	0.59	259.00	0.65	0.63	0.57
221.00	0.65	0.61	0.59	260.00	0.65	0.63	0.57
222.00	0.65	0.61	0.60	261.00	0.64	0.63	0.57
223.00	0.65	0.61	0.60	262.00	0.64	0.63	0.57
224.00	0.65	0.61	0.59	263.00	0.64	0.63	0.58
225.00	0.65	0.61	0.59	264.00	0.64	0.63	0.58
226.00	0.65	0.61	0.59	265.00	0.65	0.63	0.58
227.00	0.65	0.61	0.59	266.00	0.65	0.63	0.59
228.00	0.65	0.61	0.59	267.00	0.65	0.63	0.59
229.00	0.65	0.61	0.59	268.00	0.65	0.62	0.59
230.00	0.65	0.61	0.59	269.00	0.65	0.62	0.59
231.00	0.65	0.61	0.59	270.00	0.65	0.63	0.59
232.00	0.64	0.62	0.59	271.00	0.65	0.63	0.59
233.00	0.65	0.62	0.58	272.00	0.65	0.63	0.59
234.00	0.65	0.62	0.58	273.00	0.65	0.63	0.59
235.00	0.65	0.62	0.58	274.00	0.65	0.62	0.59
236.00	0.65	0.62	0.58	275.00	0.65	0.62	0.59
237.00	0.65	0.62	0.58	276.00	0.65	0.62	0.59
238.00	0.64	0.62	0.59	277.00	0.65	0.62	0.59
239.00	0.64	0.63	0.59	278.00	0.65	0.62	0.59
240.00	0.65	0.63	0.58	279.00	0.65	0.62	0.59
241.00	0.65	0.63	0.59	280.00	0.65	0.62	0.60
242.00	0.66	0.63	0.59	281.00	0.65	0.62	0.60
243.00	0.66	0.62	0.59	282.00	0.65	0.62	0.60
244.00	0.66	0.62	0.59	283.00	0.65	0.62	0.60
245.00	0.66	0.62	0.59	284.00	0.65	0.62	0.60
246.00	0.66	0.62	0.59				

APPENDIX 6 (continued)

A time series chart was drawn for each of the replications. The chart showed that after the model was run for long enough the results of the three replications converged and became horizontal. According to the employed method, the greater is the convergence in the replications the greater is the confidence of results. See the figure below.



Given that in the figure above the three replications converge and become horizontal after 220 a period of hours, any run length of 220 hours or longer will be a proper length for the proposed simulation model. Beyond this point both convergence and confidence would not significantly improve.

APPENDIX 7

**INCREASED PRODUCT VARIETY SCENARIO; ADDITIONAL PROCESS ROUTINGS
AND TIMES**

Product	Sequence	Location	Distr. name	Timing (minutes)		Distr. name	Timing (minutes)	
				Average	SD		Set-up	SD
F	1	WC3	dnd time 6~3	21	0.62	dnd set up WC3	20	2.9
F	2	WC6	dnd time 6~6	11	0.92	dnd set up WC6	29	3.9
F	3	WC7	dnd time 6~7	16	0.58	dnd set up WC7	28	3.4
F	4	WC8	dnd time 6~8	13	0.75	dnd set up WC8	27	2.8
F	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A
G	1	WC3	dnd time 7~3	23	0.64	dnd set up WC3	20	2.9
G	2	WC5	dnd time 7~5	11	0.91	dnd set up WC5	25	4.6
G	3	WC8	dnd time 7~8	15	0.82	dnd set up WC8	27	2.8
G	4	WC9	dnd time 7~9	13	0.54	dnd set up WC9	22	1.9
G	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A
H	1	WC1	dnd time 8~1	8	0.49	dnd set up WC1	21	1.7
H	2	WC6	dnd time 8~6	10	0.68	dnd set up WC6	29	3.9
H	3	WC7	dnd time 8~7	15	0.76	dnd set up WC7	28	3.4
H	4	WC9	dnd time 8~9	14	0.79	dnd set up WC9	22	1.9
H	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A
I	1	WC2	dnd time 9~2	21	0.69	dnd set up WC2	23	5
I	2	WC4	dnd time 9~4	9	0.68	dnd set up WC4	26	2.3
I	3	WC5	dnd time 9~5	13	0.75	dnd set up WC5	25	4.6
I	4	WC7	dnd time 9~7	15	0.73	dnd set up WC7	28	3.4
I	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A
J	1	WC1	dnd time 10~1	8	0.59	dnd set up WC1	21	1.7
J	2	WC6	dnd time 10~6	11	0.95	dnd set up WC6	29	3.9
J	3	WC8	dnd time 10~8	9	0.86	dnd set up WC8	27	2.8
J	4	WC9	dnd time 10~9	13	0.91	dnd set up WC9	22	1.9
J	5	Shipping	dnd shipping	12	N/A	N/A	N/A	N/A

APPENDIX 8

DEFINITION OF RANGES AND FACTOR LEVELS

In order to define the levels and ranges of the selected design factors, a series of simulation runs have been conducted. Given that operative parameters of the baseline model have been slightly modified in order to represent each of the disturbance scenarios mentioned in chapter 6; each of the scenarios yields different results with respect to other scenarios. Even though the models representing the different scenarios are derived from a baseline model, each disturbance scenario is a simulation model with specific characteristics and behaviour, and therefore it has been decided to determine specific ranges and factor levels in accordance to each scenario.

To select the levels for the considered design factors, it was first necessary to set general ranges for all the factors regardless of experimental scenario. The following sections describe the setting of ranges and their relevant parameters for each of the design factors.

1. Skill level of operators

Operators have been classified in three different groups according to their skill level:

- a) **Unskilled operators.** Those operators who, because their lack of training and experience, cannot operate more than one machine.
- b) **Semi skilled operators.** Operators who have already been trained to a certain extent and they have more experience than unskilled operators. Semi skilled operators are able to run up to a maximum of three different machines.
- c) **Skilled operators.** Those operators whose experience and level of training is significant. Skilled operators are able to run up to a maximum of five different machines within the system.

In relation to the level of skill, a usage cost per minute has been allocated to each category of operator. Thus, the employment of an unskilled operator costs \$0.16 per minute; a semi skilled operator costs \$0.21 per minute and a skilled operator costs \$0.27 per minute.

Having categorized operators according to a level of skill and usage cost, a range comprising different skill configurations within the system was defined. The skill configurations are the following:

APPENDIX 8 (continued)

- L0: 4 unskilled operators and 2 semi-skilled operators.
- L1: 3 unskilled operators and 3 semi-skilled operators.
- L2: 2 unskilled operators and 4 semi-skilled operators.
- L3: 1 unskilled operator and 5 semi-skilled operators.
- L4: 0 unskilled operators and 6 semi-skilled operators.
- L5: 4 unskilled operators, 1 semi-skilled operators and 1 skilled operator.
- L6: 3 unskilled operators, 2 semi-skilled operators and 1 skilled operator.
- L7: 2 unskilled operators, 3 semi-skilled operators and 1 skilled operator.
- L8: 1 unskilled operator, 4 semi-skilled operators and 1 skilled operator.
- L9: 0 unskilled operators, 5 semi-skilled operators and 1 skilled operator.
- L10: 0 unskilled operators, 4 semi-skilled operators and 2 skilled operators.
- L11: 0 unskilled operators, 3 semi-skilled operators and 3 skilled operators.
- L12: 0 unskilled operators, 2 semi-skilled operators and 4 skilled operators.
- L13: 0 unskilled operators, 1 semi-skilled operator and 5 skilled operators.
- L14: 0 unskilled operators, 0 semi-skilled operators and 6 skilled operators.
- L15: 4 unskilled operators, 0 semi-skilled operators and 2 skilled operators.
- L16: 3 unskilled operators, 0 semi-skilled operators and 3 skilled operators.
- L17: 2 unskilled operators, 0 semi-skilled operators and 4 skilled operators.
- L18: 1 unskilled operator, 0 semi-skilled operators and 5 skilled operators.

For each of the previous skill configurations or levels different work centre allocations were made. See the table below.

Operator	Allocated work centres									
	L0	L1	L2	L3	L4	L5	L6	L7	L8	L9
Oper1	1	1	1	1	1,6	1	1	1	1,5	1,5
Oper2	2	2	2	1,2	2,5	2	1,2	1,2	2,3	2,3
Oper3	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4
Oper4	5,7,8	5,7	5,7	5,7	7,6	5	5	5,8	5,8	5,8
Oper5	6	6,8	6,8	6,8	8,5	6	6	6	6	6,1
Oper6	9	9	8,9	8,9	9,4	6,7,8,9	6,7,8,9	6,7,8,9	6,7,8,9	6,7,8,9

Operator	Allocated work centres									
	L10	L11	L12	L13	L14	L15	L16	L17	L18	
Oper1	1,2,5,6	1,2,5,6	1,2,5,6	1,2,5,6	1,2,5,6	1	1	1	1	
Oper2	1,2	1,2	1,2	1,2	2,3,4,5	2	2	2	1,2,5,6	
Oper3	3,4	3,4	2,3,4,5	2,3,4,5	2,3,4,5	2,3,4,5	2,3,4,5	2,3,4,5	2,3,4,5	
Oper4	5,7,8,9	5,7,8,9	5,7,8,9	5,7,8,9	5,7,8,9	6	1,6,7,8	1,6,7,8	1,6,7,8	
Oper5	6,7	6,7	6,7	5,6,7,8	5,6,7,8	7	6	5,6,7,8	5,6,7,8	
Oper6	8,9	4,5,8,9	4,5,8,9	4,5,8,9	4,5,8,9	4,5,8,9	4,5,8,9	4,5,8,9	4,5,8,9	

Thus, for skill level 0 (L0) the four unskilled operators are operators 1,2,5, and 6 who run machines 1,2,6, and 9 respectively; and the two semi skilled operators are operator 3 (running machines 3 and 4) and operator 4 (running machines 5, 7, and 8).

APPENDIX 8 (continued)

2. System capacity to hold in-process inventories (buffer capacity)

A range consisting of 16 different levels, each with specific maximum capacity for both input and output buffers, has been defined. It has been assumed that storage costs increase together with storage capacity; therefore there is a storage cost associated to each capacity level. See the list below:

- L0: Buffer capacity of up to 5 parts. Cost per item per minute \$0.01.
- L1: Buffer capacity of up to 8 parts. Cost per item per minute \$0.01.
- L2: Buffer capacity of up to 9 parts. Cost per item per minute \$0.01.
- L3: Buffer capacity of up to 10 parts. Cost per item per minute \$0.01.
- L4: Buffer capacity of up to 11 parts. Cost per item per minute \$0.015.
- L5: Buffer capacity of up to 12 parts. Cost per item per minute \$0.015.
- L6: Buffer capacity of up to 13 parts. Cost per item per minute \$0.015.
- L7: Buffer capacity of up to 14 parts. Cost per item per minute \$0.015.
- L8: Buffer capacity of up to 15 parts. Cost per item per minute \$0.015.
- L9: Buffer capacity of up to 16 parts. Cost per item per minute \$0.02.
- L10: Buffer capacity of up to 17 parts. Cost per item per minute \$0.02.
- L11: Buffer capacity of up to 18 parts. Cost per item per minute \$0.02.
- L12: Buffer capacity of up to 19 parts. Cost per item per minute \$0.02.
- L13: Buffer capacity of up to 20 parts. Cost per item per minute \$0.02.
- L14: Buffer capacity of up to 21 parts. Cost per item per minute \$0.03.
- L15: Buffer capacity of up to 23 parts. Cost per item per minute \$0.03.
- L16: Buffer capacity of up to 25 parts. Cost per item per minute \$0.03.

3. Number of automated guided vehicles

The range for this factor comprises different levels, each with a specific number of vehicles operating within the system. See the list below.

- L0: One vehicle servicing all the work centres
- L1: Two vehicles servicing all the work centres.
- L2: Three vehicles servicing all the work centres.
- L3: Four vehicles servicing all the work centres.
- L4: Five vehicles servicing all the work centres.
- L5: Six vehicles servicing all the work centres.
- L6: Seven vehicles servicing all the work centres.
- L7: Eight vehicles servicing all the work centres.

APPENDIX 8 (continued)

The following assumptions have been made for all of the levels comprising this range:

- All the vehicles have the same speed and loading capacity.
- All the vehicles carry any type of product.
- There is no restriction in paths between work centres.
- No vehicle operating costs have been considered.

4. Speed of automated guided vehicles

Different vehicle speeds have been considered in this range. See the list below.

L0: Vehicle speed 1

L1: Vehicle speed 5

L2: Vehicle speed 10

L3: Vehicle speed 15

L4: Vehicle speed 20

L5: Vehicle speed 25

L6: Vehicle speed 30

L7: Vehicle speed 35

L8: Vehicle speed 40

L9: Vehicle speed 45

L10: Vehicle speed 50

L11: Vehicle speed 60

L12: Vehicle speed 70

L13: Vehicle speed 80

L14: Vehicle speed 90

L15: Vehicle speed 100

5. Loading capacity of automated guided vehicles

Same as for vehicle speed, a range of different capacities was defined. See the list below.

L0: Loading capacity of 1 piece.

L1: Loading capacity of 2 pieces.

L2: Loading capacity of 3 pieces.

L3: Loading capacity of 4 pieces.

L4: Loading capacity of 5 pieces.

L5: Loading capacity of 6 pieces.

L6: Loading capacity of 7 pieces.

L7: Loading capacity of 8 pieces.

L8: Loading capacity of 9 pieces.

L9: Loading capacity of 10 pieces.

L10: Loading capacity of 11 pieces.

APPENDIX 8 (continued)

L11: Loading capacity of 12 pieces.

L12: Loading capacity of 13 pieces.

L13: Loading capacity of 14 pieces.

L14: Loading capacity of 15 pieces.

For this range it has been assumed that loading and unloading time increase together with loading capacity, thus the following loading/unloading times are associated to specific loading capacities:

Loading capacity	1 to 5 parts	6 to 10 parts	11 to 15 parts
Loading time	0.5 min	1.2min	2 min
Unloading time	0.5 min	1.2 min	2 min

6. Duration of set-ups in machines

Different set-up time intervals have been considered within this range; see the list below.

L0: Set-up time between 1 and 5 minutes.

L1: Set-up time between 6 and 10 minutes.

L2: Set-up time between 11 and 15 minutes.

L3: Set-up time between 16 and 19 minutes.

L4: Set-up time between 20 and 29 minutes.

L5: Set-up time between 30 and 39 minutes.

L6: Set-up time between 40 and 49 minutes.

L7: Set-up time between 50 and 60 minutes.

The set-up times for each work centre in each level have been set according to the table below.

Work centre	Set-up time (minutes)							
	L0	L1	L2	L3	L4	L5	L6	L7
1	3	6	15	18	21	35	45	54
2	1	7	14	18	23	36	49	50
3	5	10	13	19	20	39	45	60
4	2	8	11	16	26	30	48	60
5	5	10	12	17	25	37	43	55
6	5	9	13	17	29	33	40	58
7	4	6	11	17	28	38	47	59
8	3	8	12	16	27	38	46	57
9	4	9	15	19	22	39	44	56
Min	1	6	11	16	20	30	40	50
Max	5	10	15	19	29	39	49	60
Avg	3.6	8.1	12.9	17.4	24.6	36.1	45.2	56.6

APPENDIX 8 (continued)

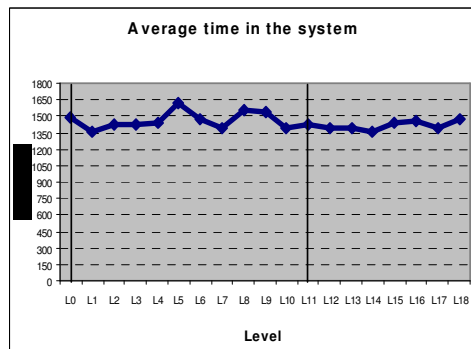
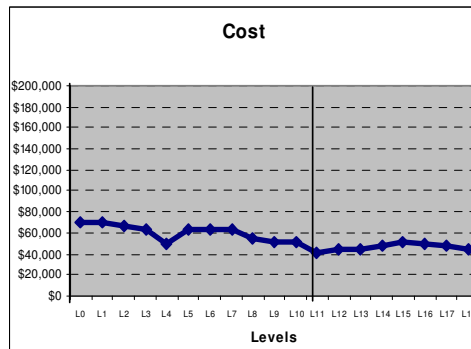
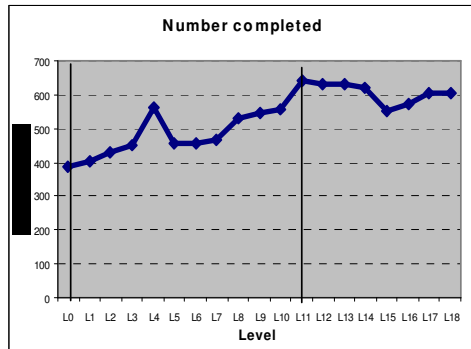
Once the ranges and their relevant parameters were set for all the design factors, a number of simulation runs were conducted to define factor levels. For each of the levels within the ranges described earlier, 50 replications of the applicable simulation model have been performed. In order to define the levels of a particular factor, each factor was adjusted according to the different levels within the range, while the rest of the factors were fixed, i.e. the levels of each factors were simulated one at a time. The same procedure was performed for the baseline model and for each of the disturbance scenarios. Factor levels were selected according to the observed performance of the disturbance scenarios in relation to the baseline simulation model; i.e. the reference performance was set by the baseline model. The baseline performance is shown in the table below.

Performance measure	Baseline performance
Number of completed parts	387 parts
Manufacturing cost	\$70,300
Time in the system	1,480 min

The figures shown in the table above reflect the performance of the baseline model as it was originally defined and after having replicated the model 50 times. Upper and lower levels of all the factors in all the experimental scenarios have been selected in accordance with the baseline performance above. As an example, the following figures show the simulation results for the different levels of two factors: skill level of operators and buffer capacity, both part of the baseline model.

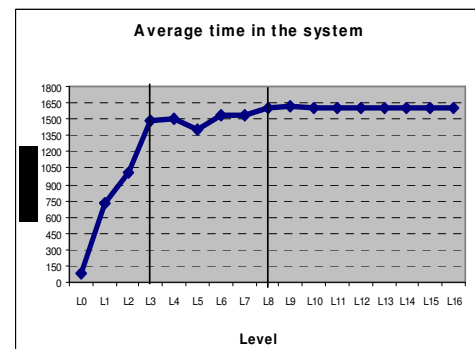
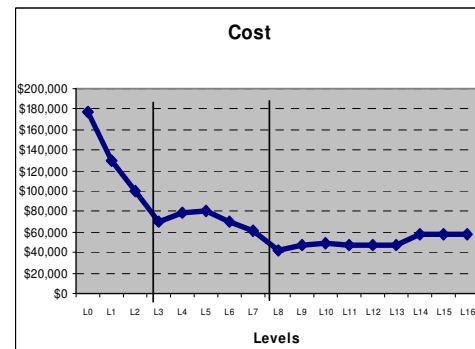
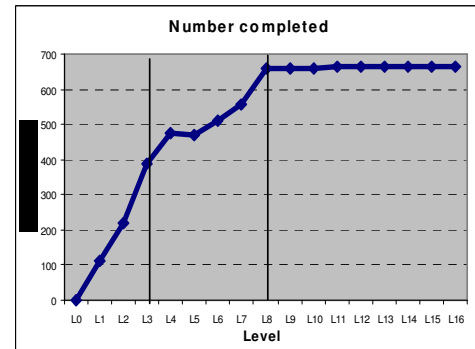
APPENDIX 8 (continued)

SKILL LEVEL OF OPERATORS



PERFORMANCE MEASURE	L0	L11
Completed parts	387	641
% of change	0%	65%
Cost (\$)	70,316	41,027
% of change	0%	-42%
Time in system (min)	1,483	1,419
% of change	0%	-4%

BUFFER CAPACITY



PERFORMANCE MEASURE	L3	L8
Completed parts	387	661
% of change	0%	71%
Cost (\$)	70,316	42,800
% of change	0%	-39%
Time in system (min)	1,483	1,610
% of change	0%	9%

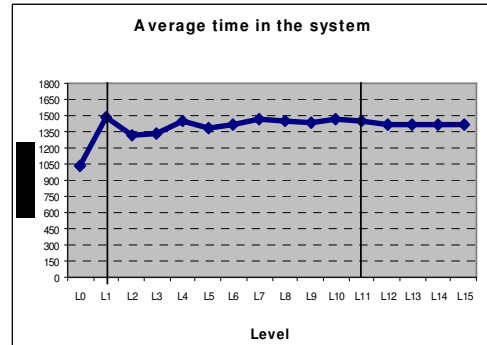
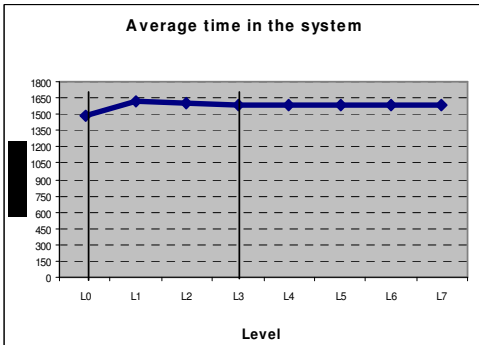
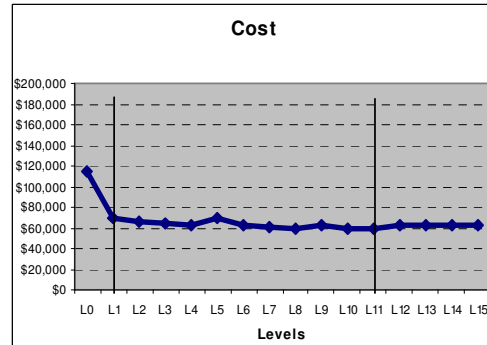
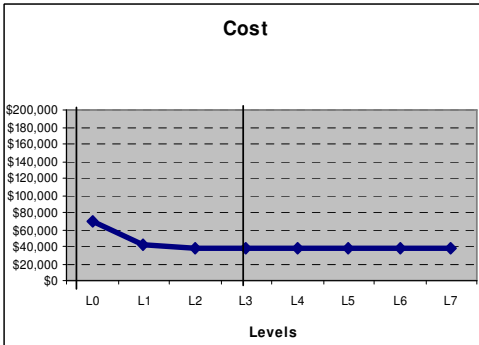
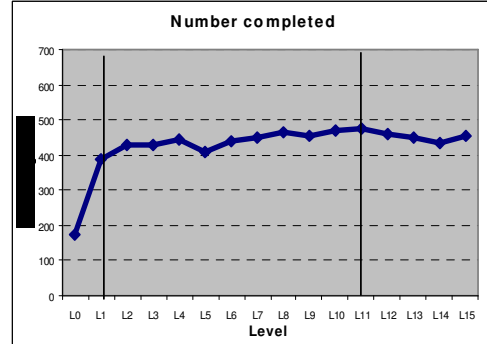
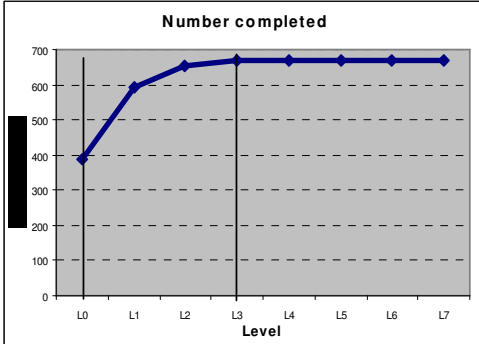
Note that in both factors lower levels have been selected according to the baseline performance defined earlier. Upper levels have been selected according to the best possible results considering the three performance indicators and with respect to the baseline performance. Thus, for the factor *skill level of operators* levels 0 and 11 have been chosen as the lower and upper levels respectively; and for the factor *buffer capacity*, level 3 as the lower level and level 8 as the upper level have been selected. The mechanics for selecting the rest of the factor levels, including those in all the disturbance scenarios, was the same as the one described for these two factors. The rest of the results and selected factor levels for the baseline model and for each of the disturbance scenarios are shown in the charts below.

APPENDIX 8 (continued)

BASELINE MODEL

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



PERFORMANCE MEASURE	L0	L3
Completed parts	387	667
% of change	0%	72%
Cost (\$)	70,316	37,617
% of change	0%	-47%
Time in system (min)	1,483	1,587
% of change	0%	6%

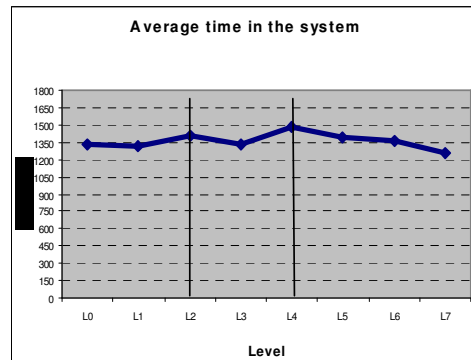
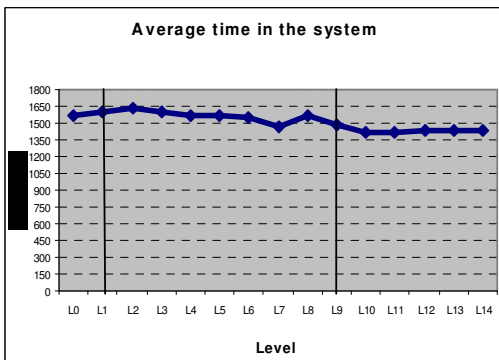
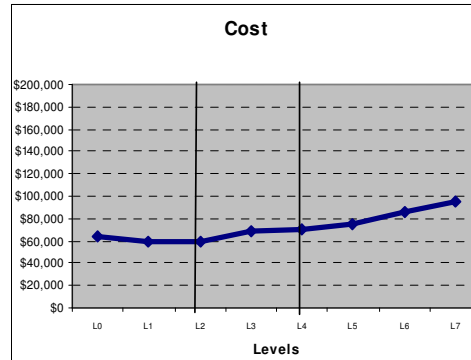
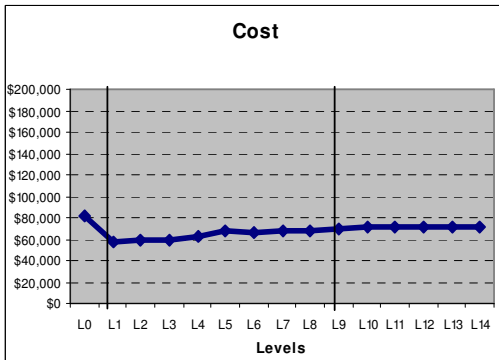
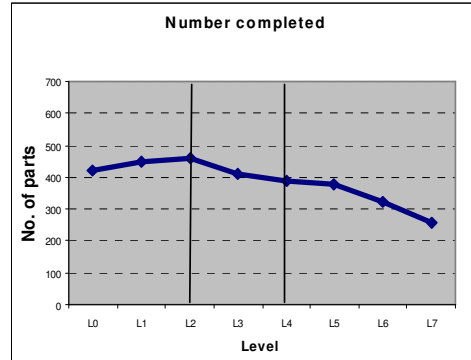
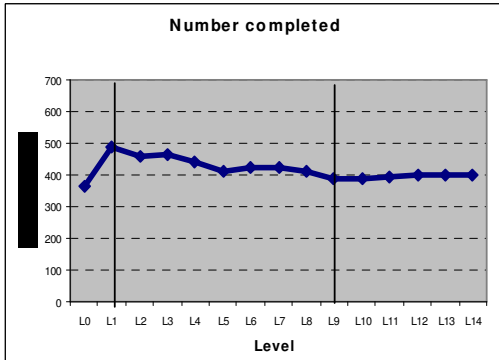
PERFORMANCE MEASURE	L1	L11
Completed parts	387	474
% of change	0%	22%
Cost (\$)	70,316	58,540
% of change	0%	-17%
Time in system (min)	1,483	1,457
% of change	0%	-2%

APPENDIX 8 (continued)

BASELINE MODEL

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**

**DURATION OF SET-UPS
IN MACHINES**



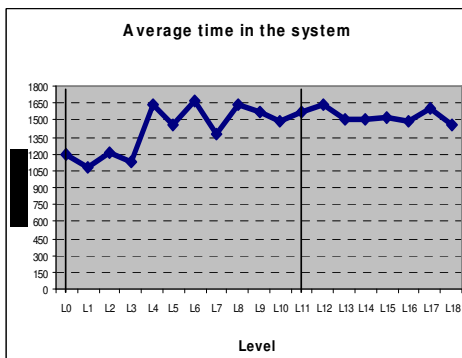
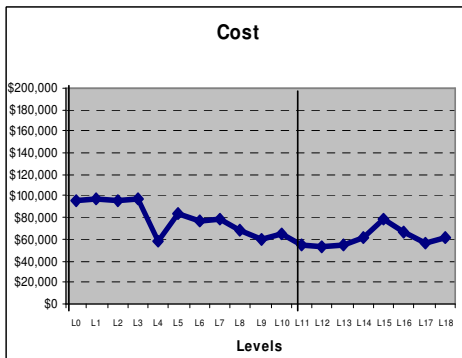
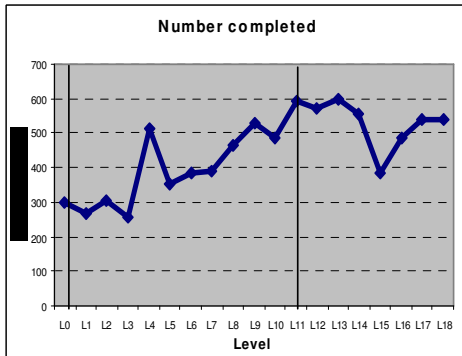
PERFORMANCE MEASURE	L1	L9
Completed parts	486	387
% of change	25%	0%
Cost (\$)	57,477	70,316
% of change	-18%	0%
Time in system (min)	1,598	1,483
% of change	8%	0%

PERFORMANCE MEASURE	L2	L4
Completed parts	458	387
% of change	18%	0%
Cost (\$)	59,357	70,316
% of change	-16%	0%
Time in system (min)	1,411	1,483
% of change	-5%	0%

APPENDIX 8 (continued)

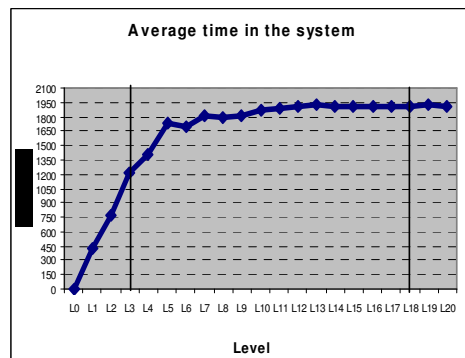
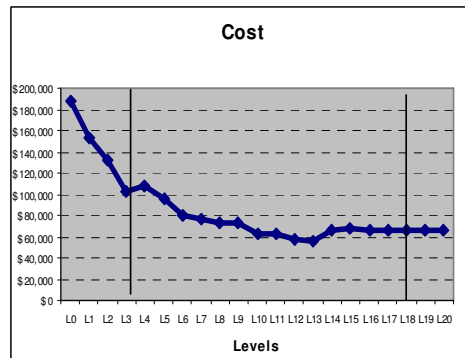
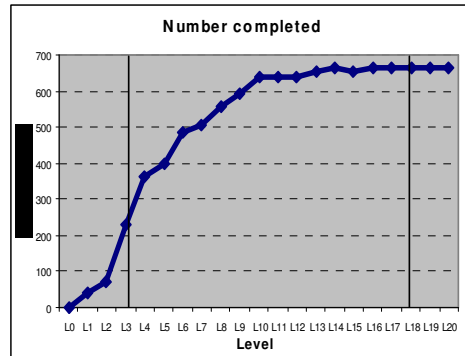
FREQUENT MACHINE BREAKDOWNS SCENARIO

SKILL LEVEL OF OPERATORS



PERFORMANCE MEASURE	L0	L11
Completed parts	297	596
% of change	0%	101%
Cost (\$)	95,814	54,442
% of change	0%	-43%
Time in system (min)	1,201	1,572
% of change	0%	31%

BUFFER CAPACITY



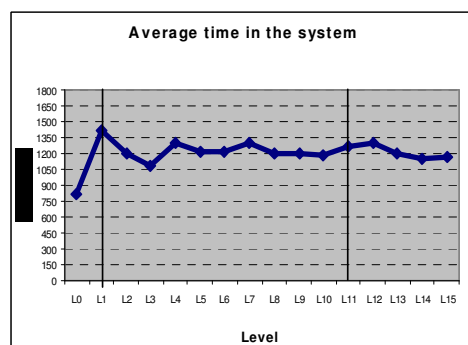
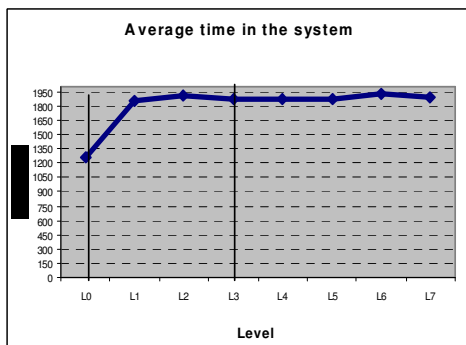
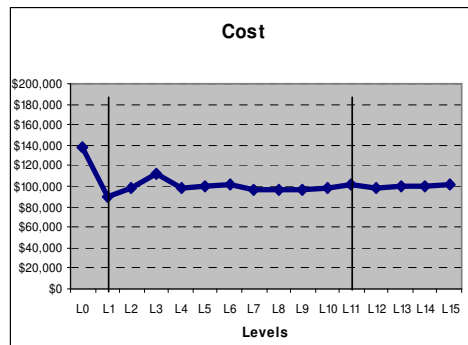
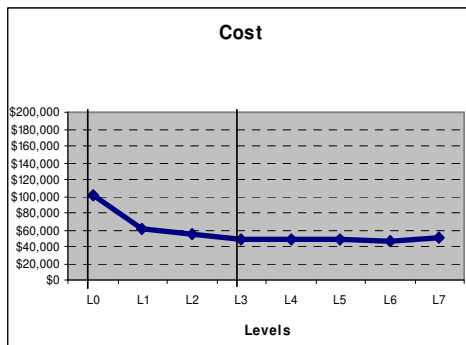
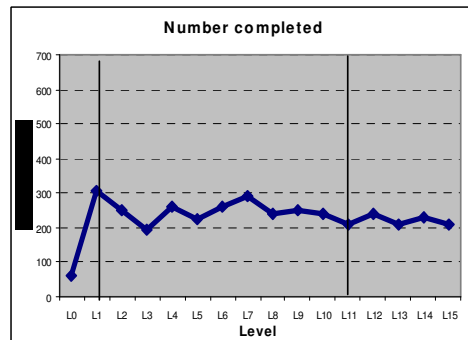
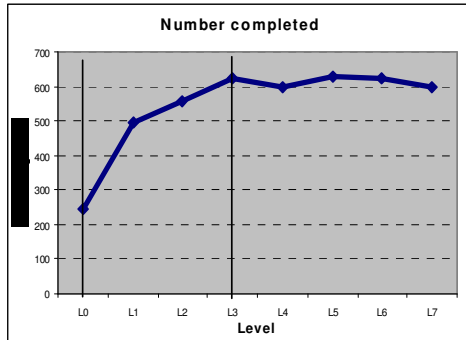
PERFORMANCE MEASURE	L3	L18
Completed parts	230	666
% of change	0%	190%
Cost (\$)	103,050	66,326
% of change	0%	-36%
Time in system (min)	1,215	1,907
% of change	0%	57%

APPENDIX 8 (continued)

FREQUENT MACHINE BREAKDOWNS SCENARIO

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



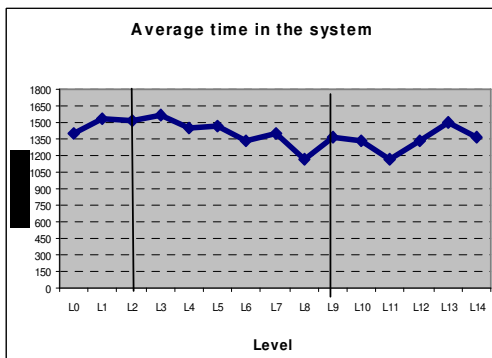
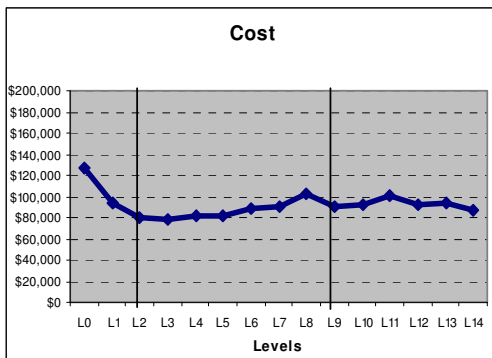
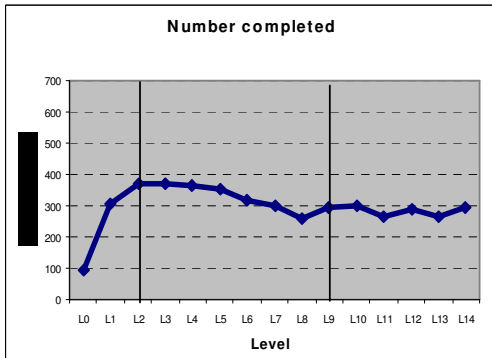
PERFORMANCE MEASURE	L0	L3
Completed parts	247	624
% of change	0%	152%
Cost (\$)	101,373	48,619
% of change	0%	-88%
Time in system (min)	1,250	1,864
% of change	0%	33%

PERFORMANCE MEASURE	L1	L11
Completed parts	305	210
% of change	0%	-31%
Cost (\$)	88,799	102,045
% of change	0%	15%
Time in system (min)	1,414	1,260
% of change	0%	-11%

APPENDIX 8 (continued)

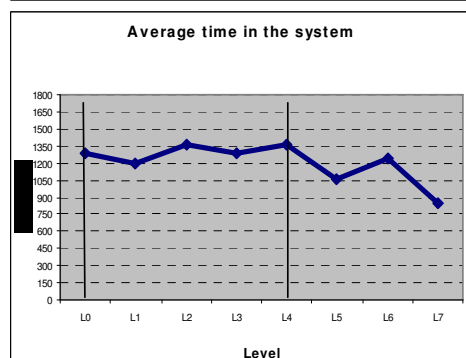
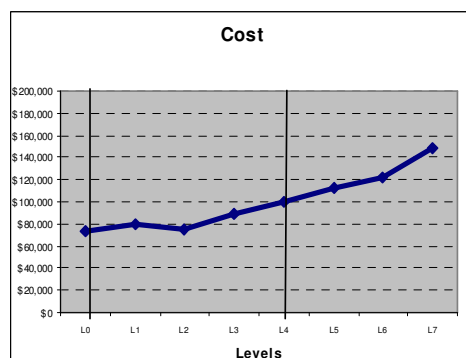
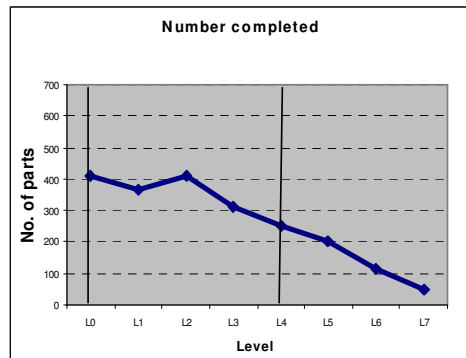
FREQUENT MACHINE BREAKDOWNS SCENARIO

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**



PERFORMANCE MEASURE	L2	L9
Completed parts	373	294
% of change	27%	0%
Cost (\$)	80,766	89,961
% of change	-10%	0%
Time in system (min)	1,512	1,362
% of change	11%	0%

**DURATION OF SET-UPS
IN MACHINES**



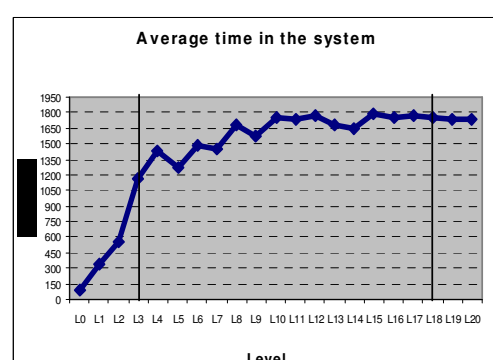
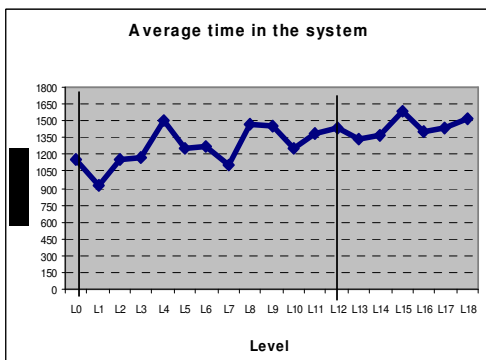
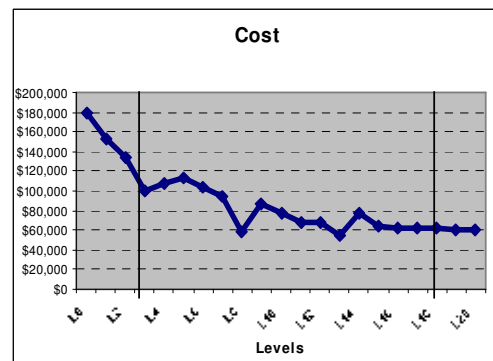
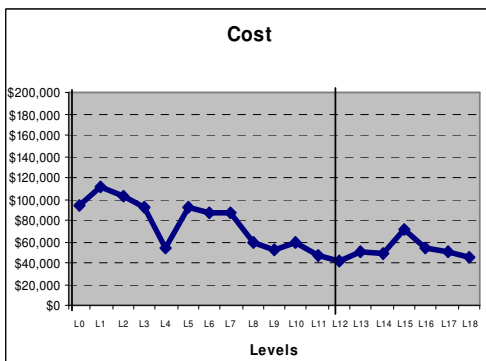
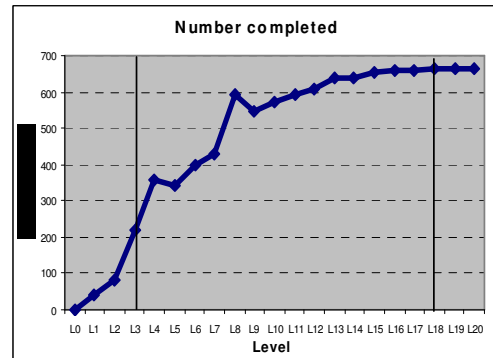
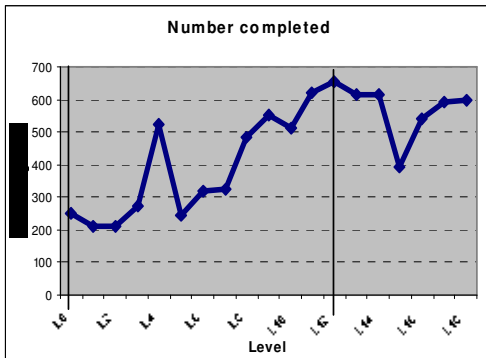
PERFORMANCE MEASURE	L0	L4
Completed parts	408	250
% of change	63%	0%
Cost (\$)	73,673	100,739
% of change	-27%	0%
Time in system (min)	1,280	1,364
% of change	-6%	0%

APPENDIX 8 (continued)

FREQUENT OPERATOR UNAVAILABILITY SCENARIO

SKILL LEVEL OF OPERATORS

BUFFER CAPACITY



PERFORMANCE MEASURE	L0	L12
Completed parts	249	656
% of change	0%	163%
Cost (\$)	94,676	42,018
% of change	0%	-56%
Time in system (min)	1,158	1,434
% of change	0%	24%

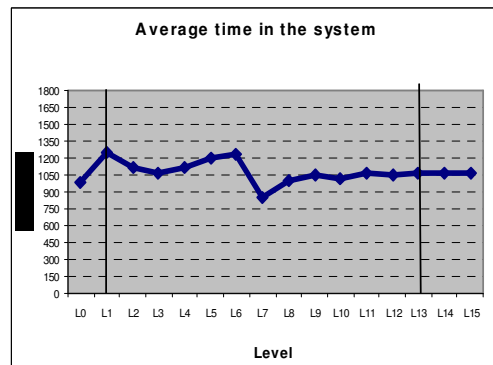
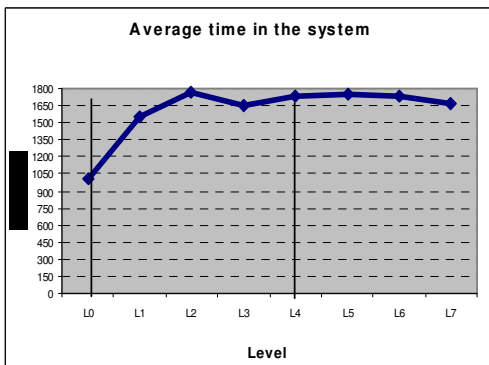
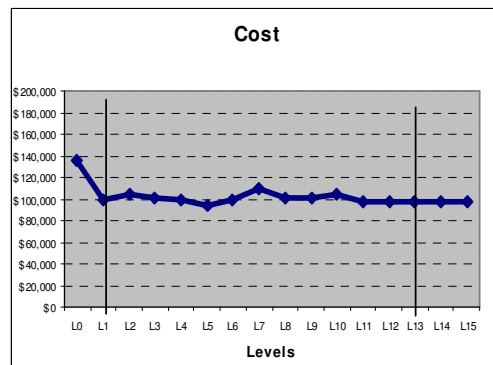
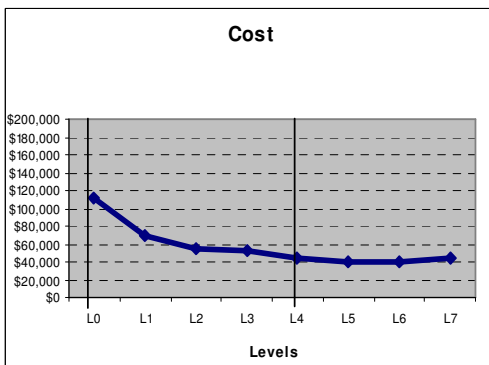
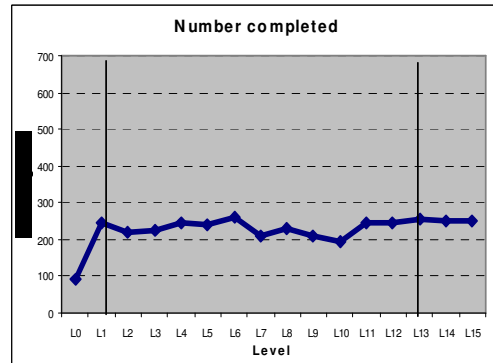
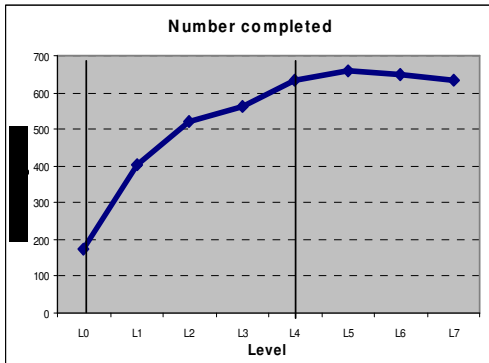
PERFORMANCE MEASURE	L3	L18
Completed parts	220	663
% of change	0%	201%
Cost (\$)	99,870	61,553
% of change	0%	-38%
Time in system (min)	1,171	1,758
% of change	0%	50%

APPENDIX 8 (continued)

FREQUENT OPERATOR UNAVAILABILITY SCENARIO

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



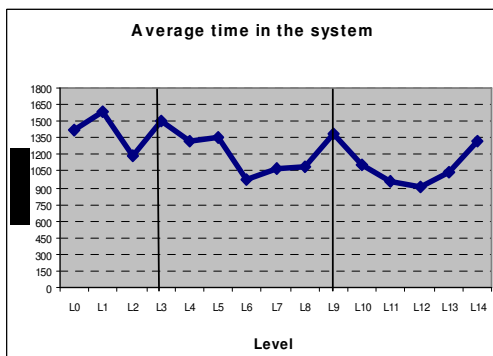
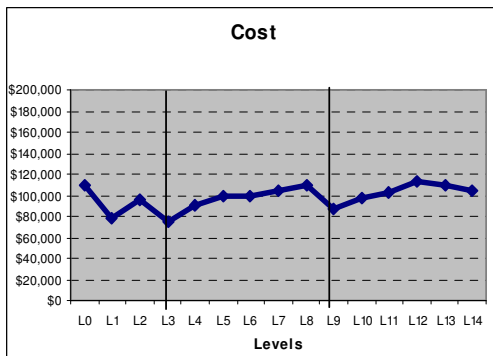
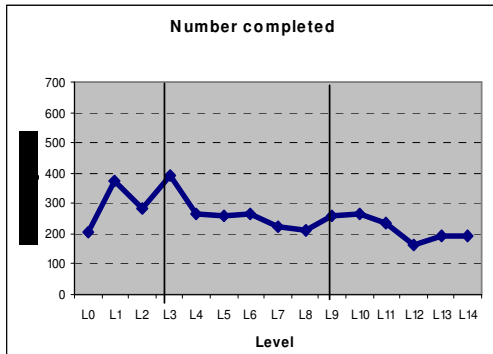
PERFORMANCE MEASURE	L0	L4
Completed parts	175	634
% of change	0%	263%
Cost (\$)	111,709	43,323
% of change	0%	-61%
Time in system (min)	1,012	1,728
% of change	0%	71%

PERFORMANCE MEASURE	L1	L13
Completed parts	247	253
% of change	0%	2%
Cost (\$)	98,540	96,543
% of change	0%	-2%
Time in system (min)	1,255	1,063
% of change	0%	-15%

APPENDIX 8 (continued)

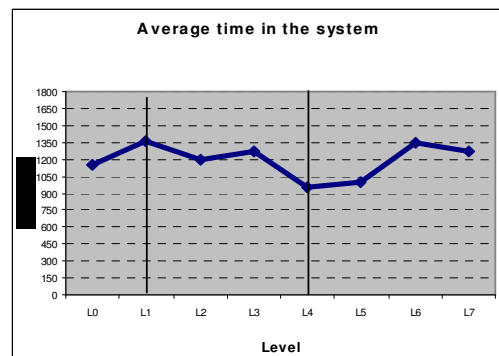
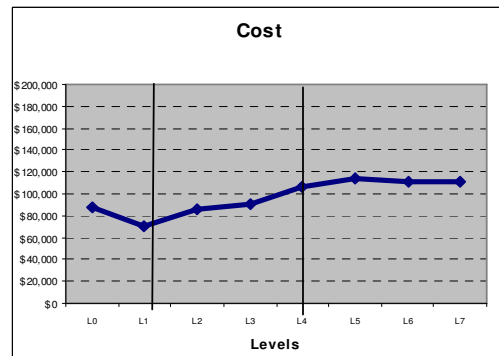
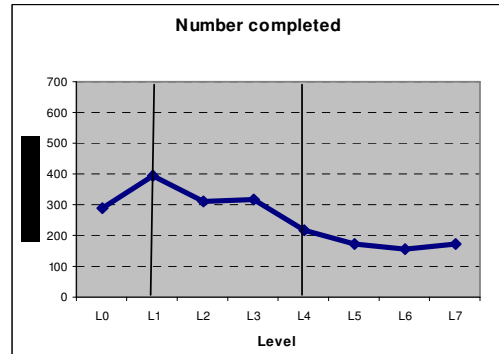
FREQUENT OPERATOR UNAVAILABILITY SCENARIO

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**



PERFORMANCE MEASURE	L3	L9
Completed parts	390	257
% of change	52%	0%
Cost (\$)	75,590	87,175
% of change	-13%	0%
Time in system (min)	1,502	1,380
% of change	9%	0%

**DURATION OF SET-UPS
IN MACHINES**



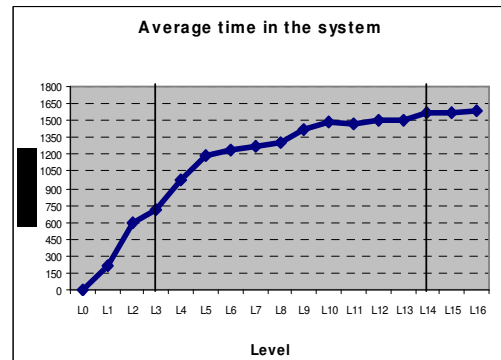
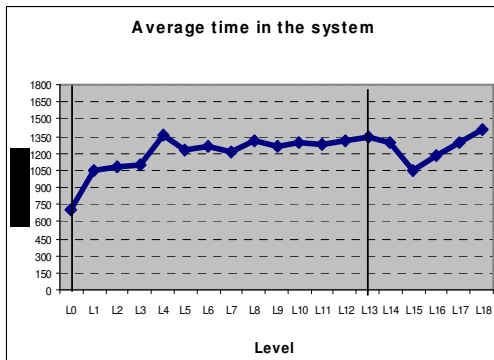
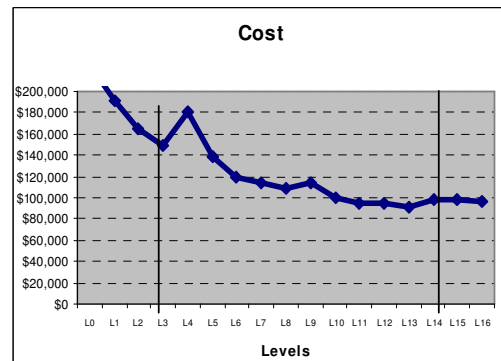
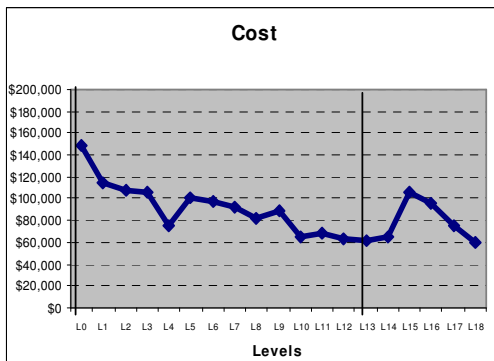
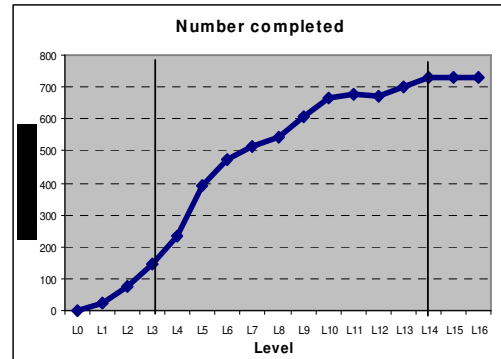
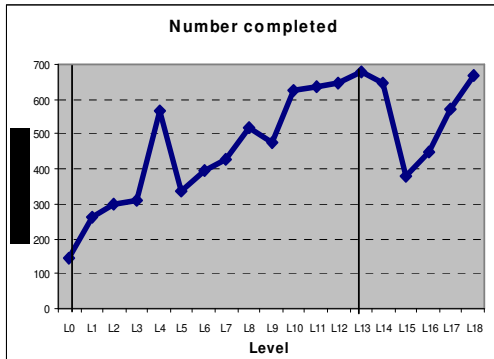
PERFORMANCE MEASURE	L1	L4
Completed parts	397	214
% of change	86%	0%
Cost (\$)	69,735	105,794
% of change	-34%	0%
Time in system (min)	1,362	950
% of change	43%	0%

APPENDIX 8 (continued)

IRREGULAR PATTERN OF RAW MATERIAL ARRIVALS

SKILL LEVEL OF OPERATORS

BUFFER CAPACITY



PERFORMANCE MEASURE	L0	L13
Completed parts	147	676
% of change	0%	361%
Cost (\$)	149,110	60,921
% of change	0%	-59%
Time (min)	705	1,341
% of change	0%	90%

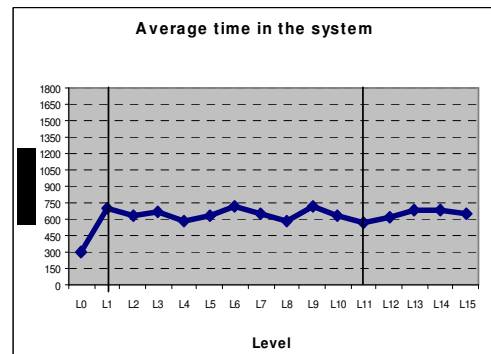
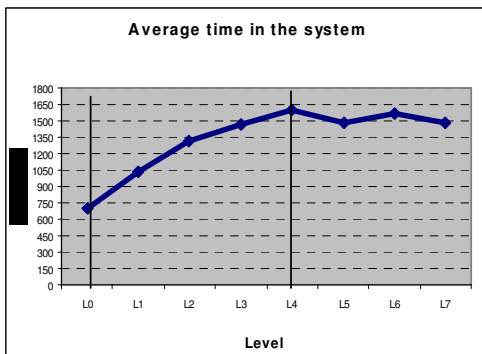
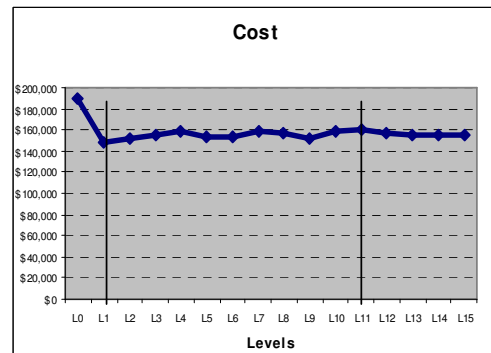
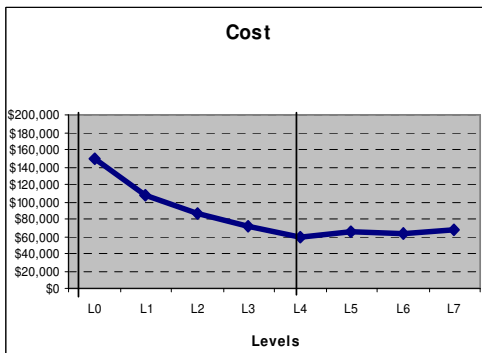
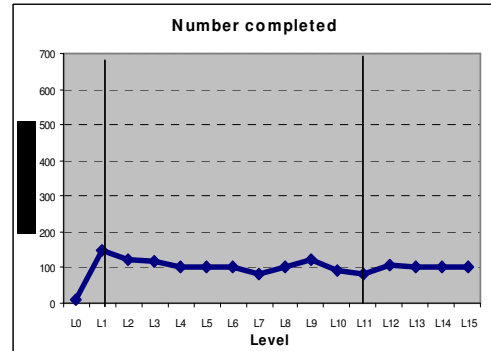
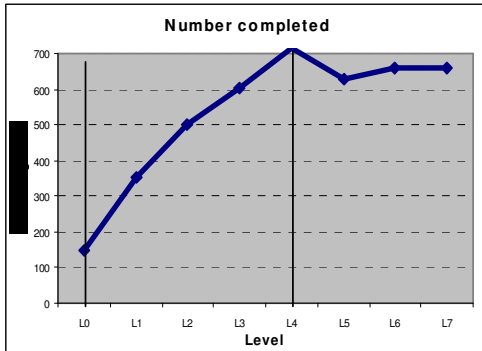
PERFORMANCE MEASURE	L3	L14
Completed parts	147	731
% of change	0%	398%
Cost (\$)	149,110	97,927
% of change	0%	-34%
Time (min)	705	1,568
% of change	0%	122%

APPENDIX 8 (continued)

IRREGULAR PATTERN OF RAW MATERIAL ARRIVALS

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



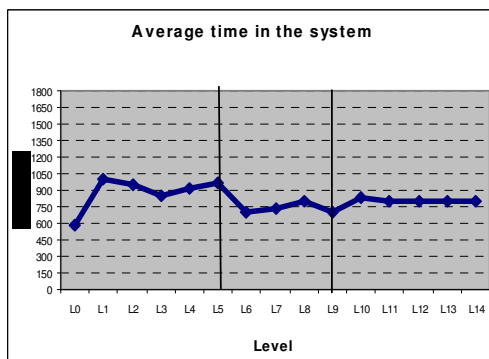
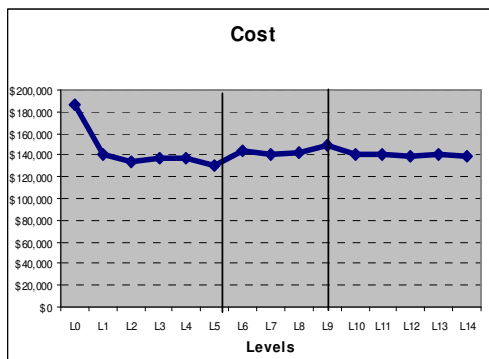
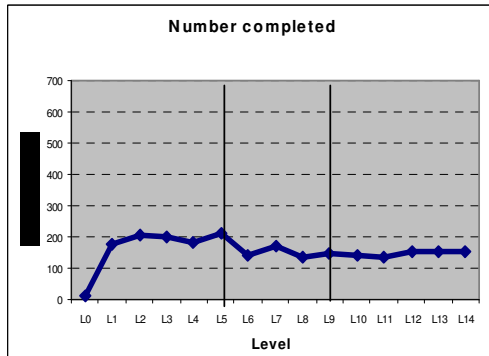
PERFORMANCE MEASURE	L0	L4
Completed parts	147	714
% of change	0%	386%
Cost (\$)	149,110	58,059
% of change	0%	-61%
Time (min)	705	1,593
% of change	0%	126%

PERFORMANCE MEASURE	L1	L11
Completed parts	147	84
% of change	0%	-43%
Cost (\$)	149,110	160,325
% of change	0%	8%
Time (min)	705	559
% of change	0%	-21%

APPENDIX 8 (continued)

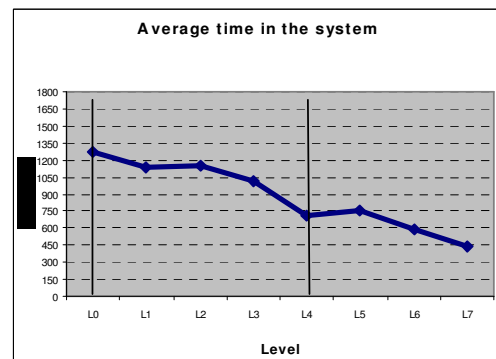
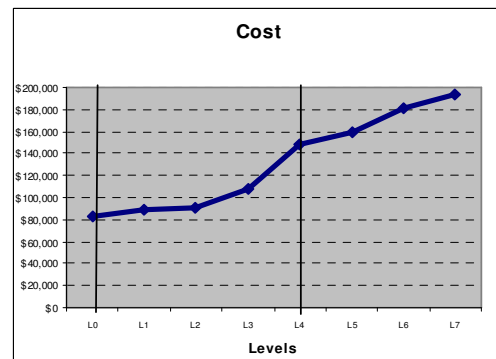
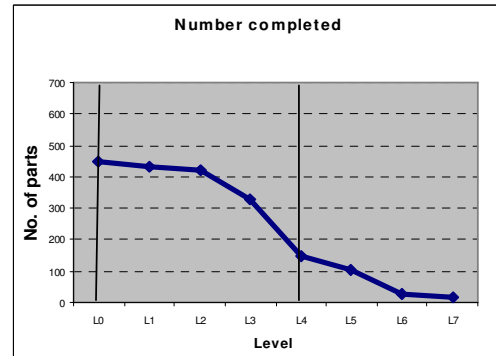
IRREGULAR PATTERN OF RAW MATERIAL ARRIVALS

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**



PERFORMANCE MEASURE	L5	L9
Completed parts	212	147
% of change	44%	0%
Cost (\$)	130,746	149,110
% of change	-12%	0%
Time (min)	966	705
% of change	37%	0%

**DURATION OF SET-UPS
IN MACHINES**



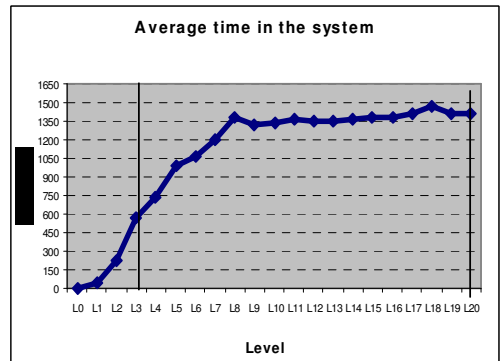
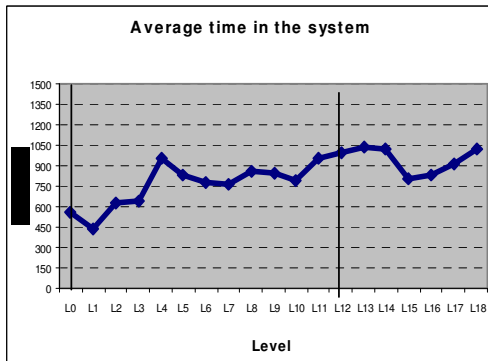
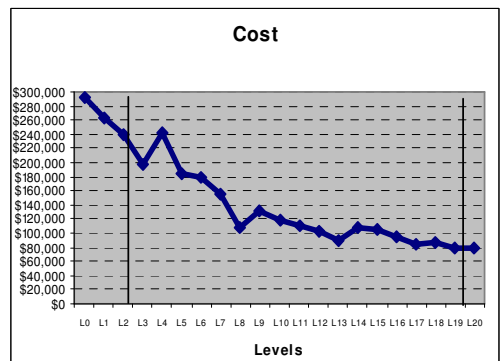
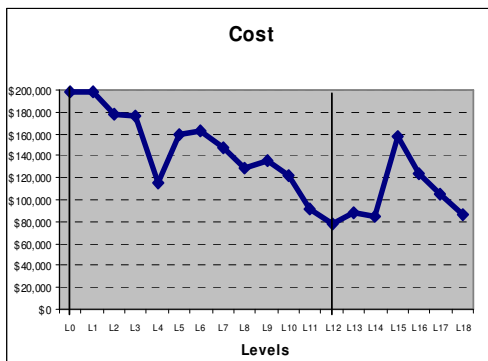
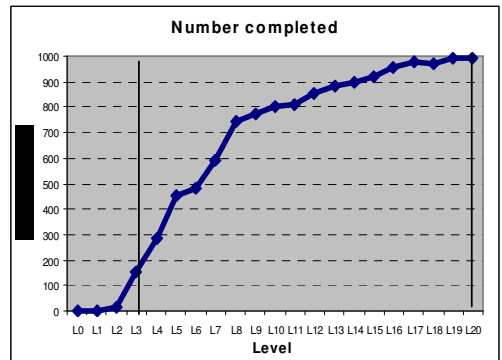
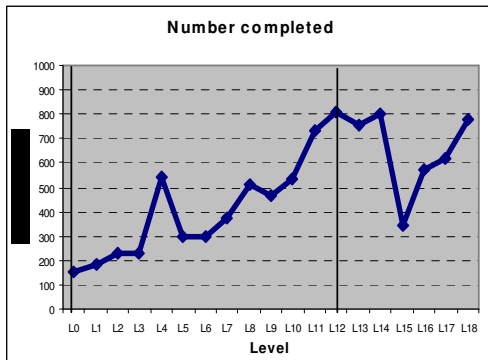
PERFORMANCE MEASURE	L0	L4
Completed parts	447	147
% of change	205%	0%
Cost (\$)	83,583	149,110
% of change	-44%	0%
Time (min)	1,264	705
% of change	79%	0%

APPENDIX 8 (continued)

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO

SKILL LEVEL OF OPERATORS

BUFFER CAPACITY



PERFORMANCE MEASURE	L0	L12
Completed parts	151	812
% of change	0%	436%
Cost (\$)	197,509	78,438
% of change	0%	-60%
Time (min)	564	995
% of change	0%	76%

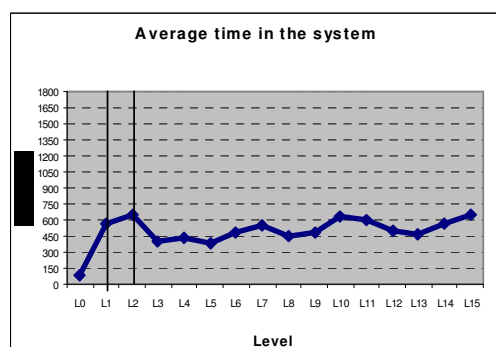
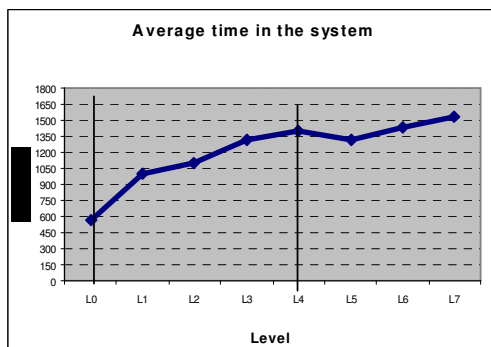
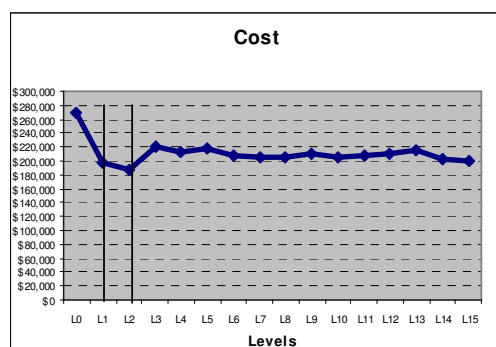
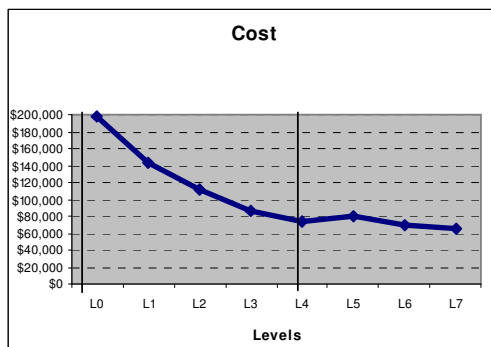
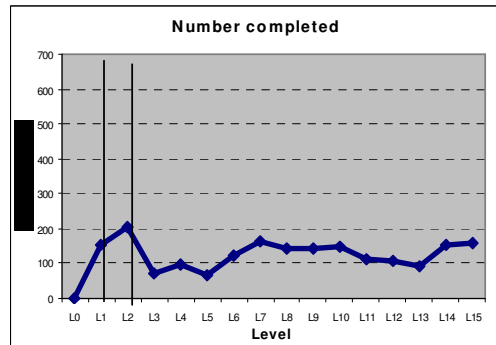
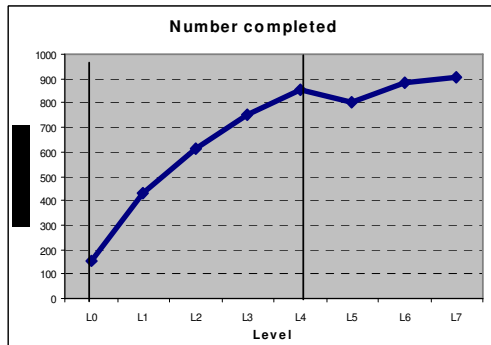
PERFORMANCE MEASURE	L3	L20
Completed parts	151	994
% of change	0%	556%
Cost (\$)	197,509	79,948
% of change	0%	-60%
Time (min)	564	1,410
% of change	0%	150%

APPENDIX 8 (continued)

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



PERFORMANCE MEASURE	L0	L4
Completed parts	151	851
% of change	0%	462%
Cost (\$)	197,509	73,364
% of change	0%	-63%
Time (min)	564	1,407
% of change	0%	149%

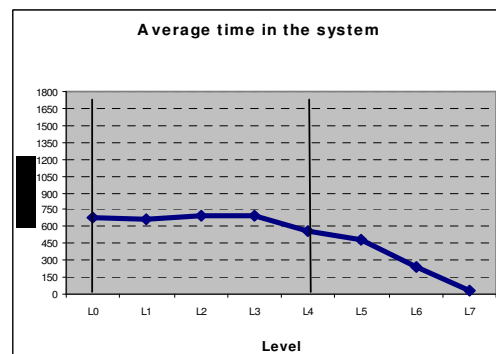
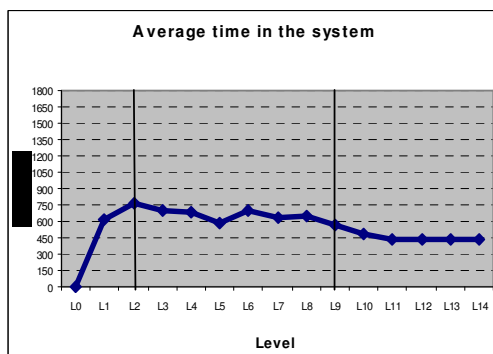
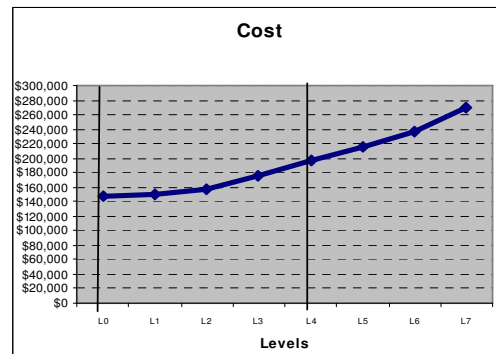
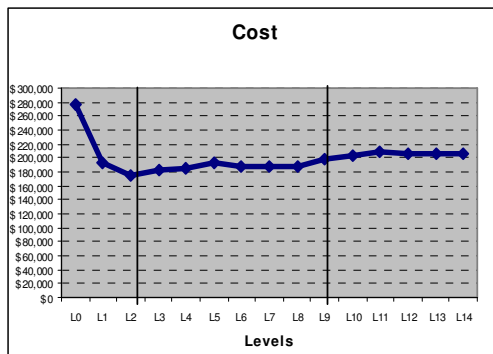
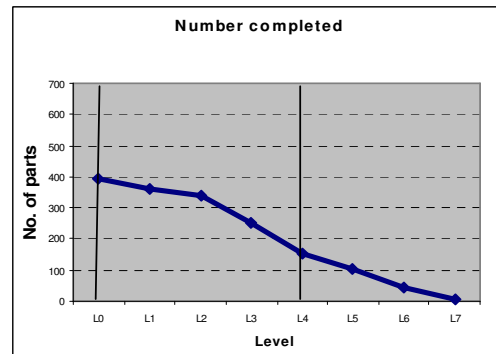
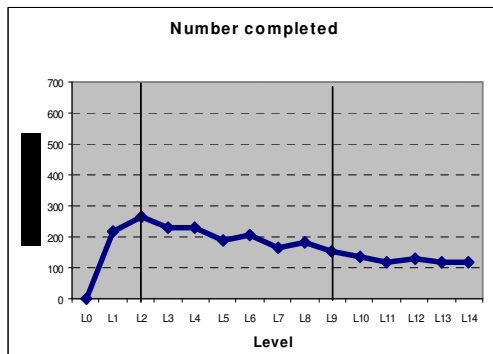
PERFORMANCE MEASURE	L1	L2
Completed parts	151	203
% of change	0%	34%
Cost (\$)	197,509	188,143
% of change	0%	-5%
Time (min)	564	655
% of change	0%	16%

APPENDIX 8 (continued)

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**

**DURATION OF SET-UPS
IN MACHINES**



PERFORMANCE MEASURE	L2	L9
Completed parts	267	151
% of change	76%	0%
Cost (\$)	173,652	197,509
% of change	-12%	0%
Time (min)	772	564
% of change	37%	0%

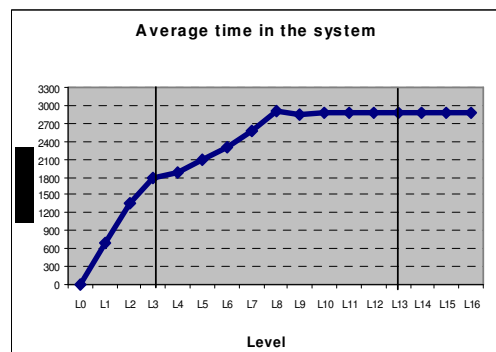
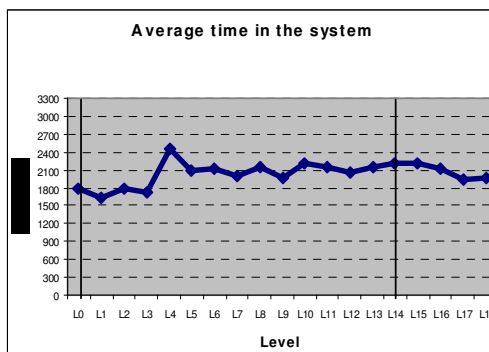
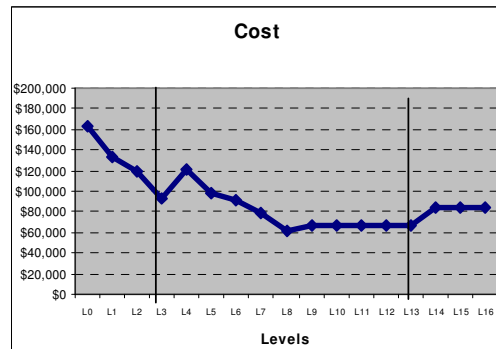
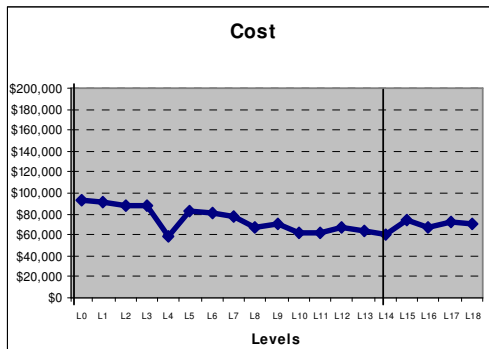
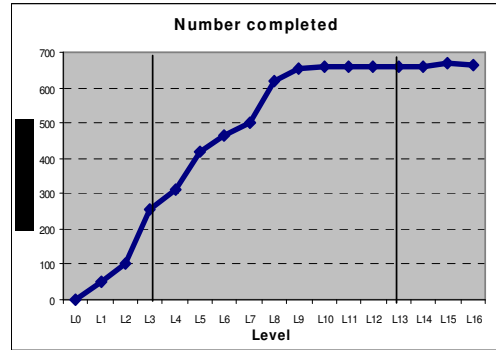
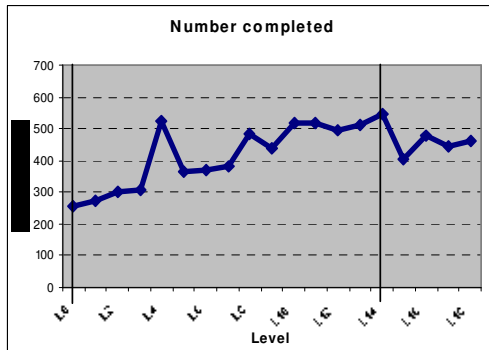
PERFORMANCE MEASURE	L0	L4
Completed parts	393	151
% of change	160%	0%
Cost (\$)	148,262	197,509
% of change	-25%	0%
Time (min)	677	564
% of change	20%	0%

APPENDIX 8 (continued)

INCREASED PRODUCT VARIETY SCENARIO

SKILL LEVEL OF OPERATORS

BUFFER CAPACITY



PERFORMANCE MEASURE	L0	L14
Completed parts	254	548
% of change	0%	115%
Cost (\$)	93,465	61,050
% of change	0%	-35%
Time (min)	1,788	2,199
% of change	0%	23%

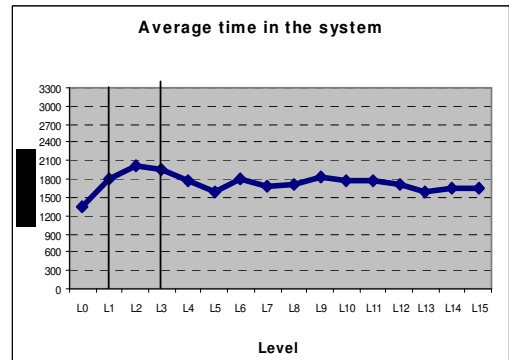
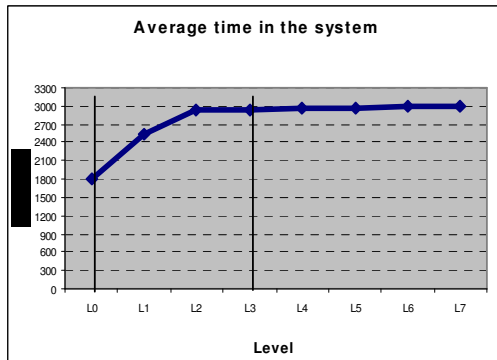
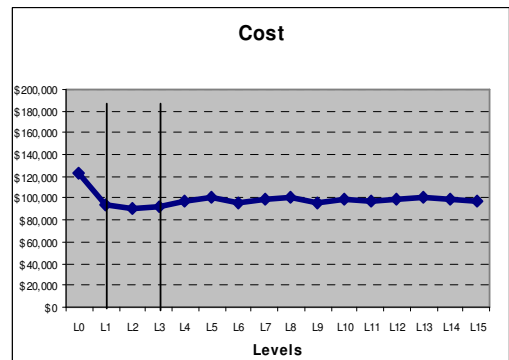
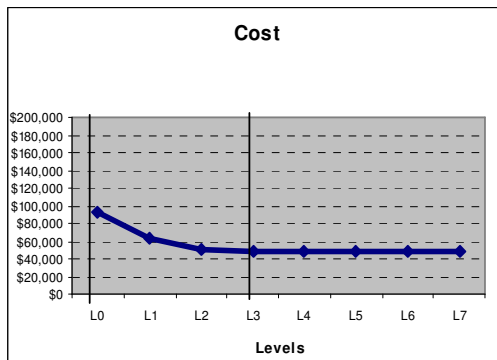
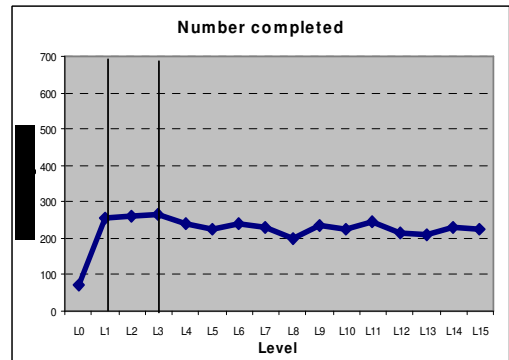
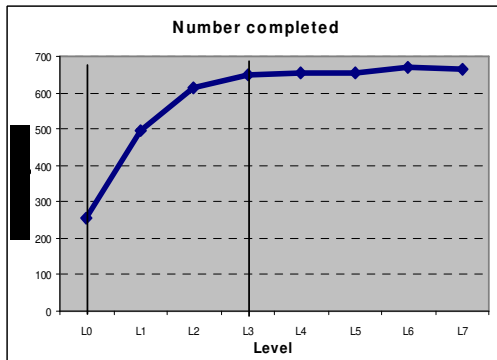
PERFORMANCE MEASURE	L3	L13
Completed parts	254	660
% of change	0%	159%
Cost (\$)	93,465	66,141
% of change	0%	-29%
Time (min)	1,788	2,873
% of change	0%	61%

APPENDIX 8 (continued)

INCREASED PRODUCT VARIETY SCENARIO

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



PERFORMANCE MEASURE	L0	L3
Completed parts	254	651
% of change	0%	256%
Cost (\$)	93,465	48,187
% of change	0%	-48%
Time (min)	1,788	2,933
% of change	0%	64%

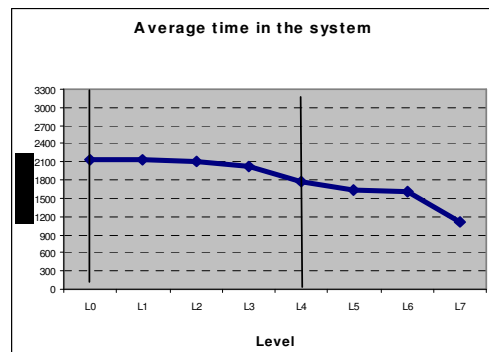
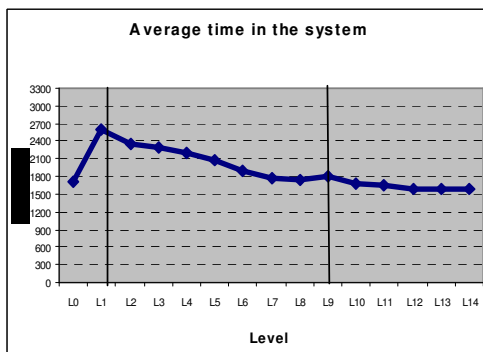
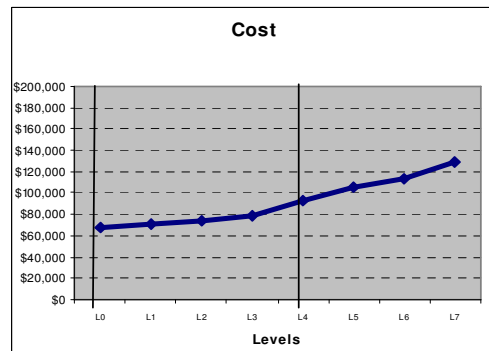
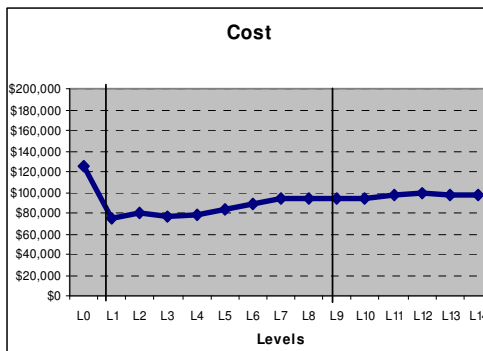
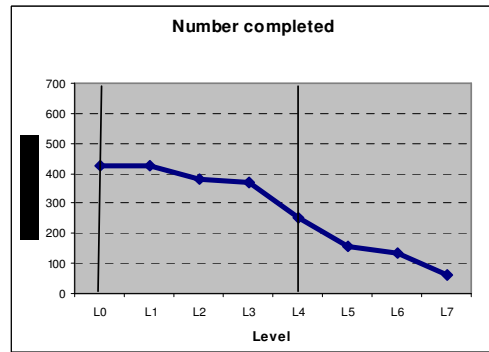
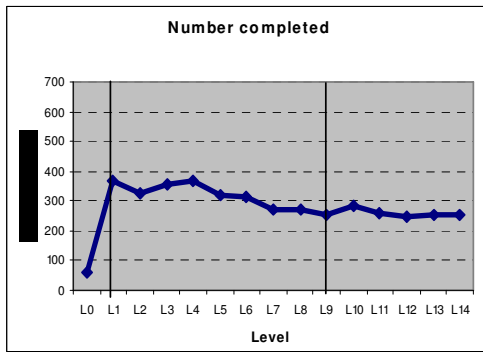
PERFORMANCE MEASURE	L1	L3
Completed parts	254	264
% of change	0%	4%
Cost (\$)	93,465	92,623
% of change	0%	-1%
Time (min)	1,788	1,943
% of change	0%	9%

APPENDIX 8 (continued)

INCREASED PRODUCT VARIETY SCENARIO

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**

**DURATION OF SET-UPS
IN MACHINES**



PERFORMANCE MEASURE	L1	L9
Completed parts	366	254
% of change	44%	0%
Cost (\$)	75,618	93,465
% of change	-19%	0%
Time (min)	2,606	1,788
% of change	46%	0%

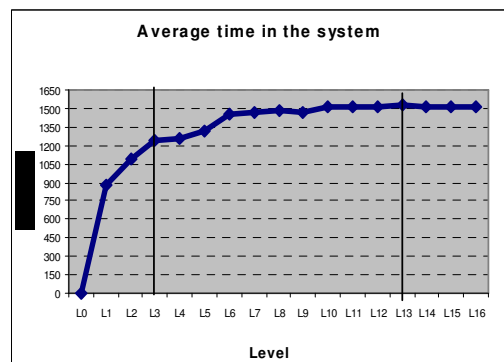
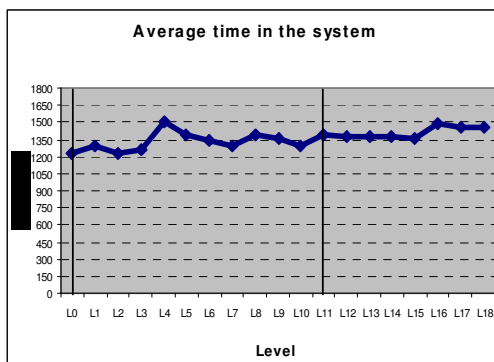
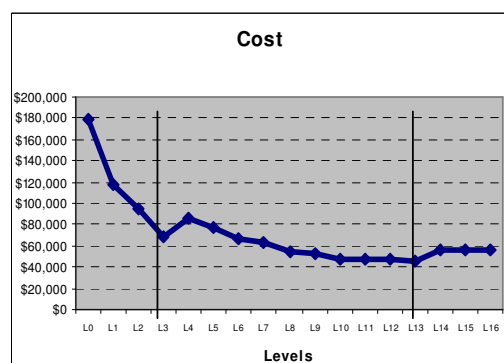
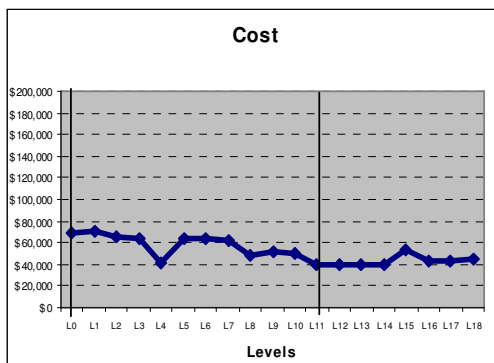
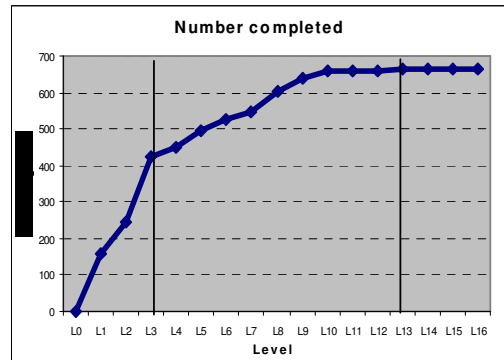
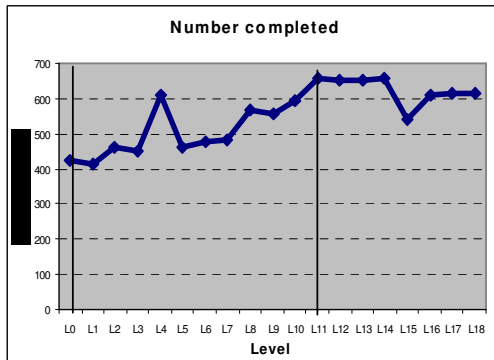
PERFORMANCE MEASURE	L0	L4
Completed parts	423	254
% of change	66%	0%
Cost (\$)	67,384	93,465
% of change	-28%	0%
Time (min)	2,144	1,788
% of change	20%	0%

APPENDIX 8 (continued)

HIGH VARIATION IN PRODUCT MIX SCENARIO

SKILL LEVEL OF OPERATORS

BUFFER CAPACITY



PERFORMANCE MEASURE	L0	L11
Completed parts	426	658
% of change	0%	55%
Cost (\$)	68,228	38,934
% of change	0%	-43%
Time (min)	1,235	1,383
% of change	0%	12%

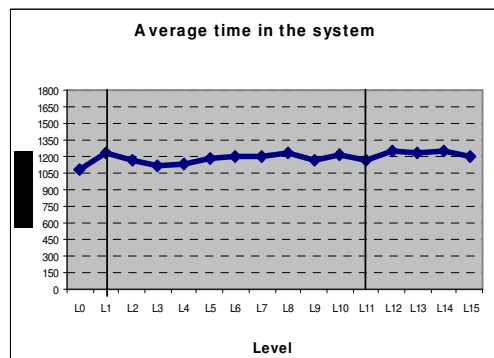
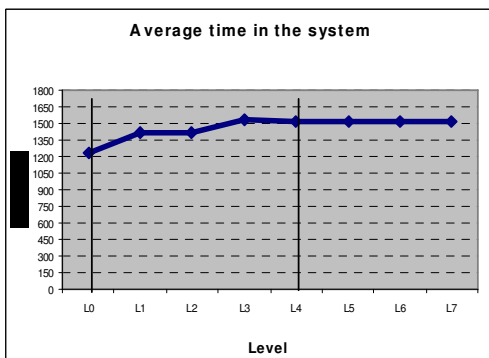
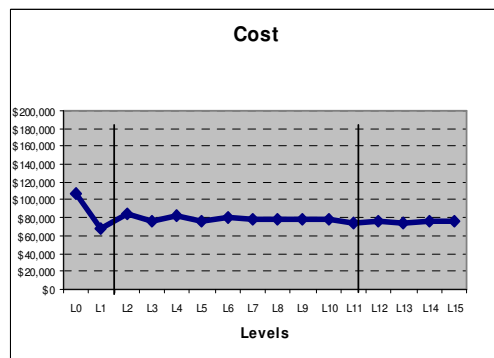
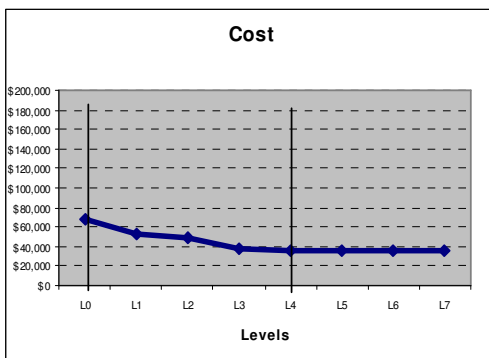
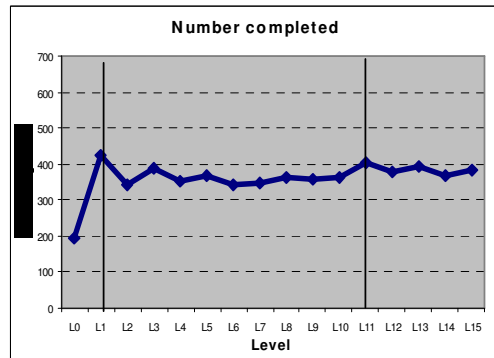
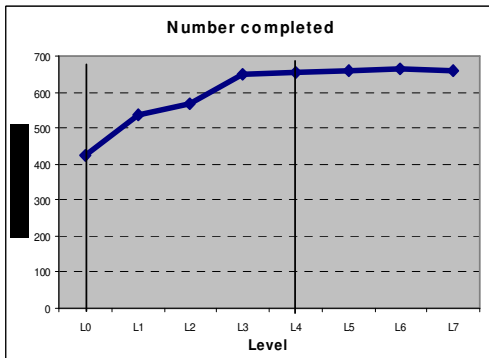
PERFORMANCE MEASURE	L3	L13
Completed parts	426	666
% of change	0%	56%
Cost (\$)	68,228	46,043
% of change	0%	-33%
Time (min)	1,235	1,523
% of change	0%	23%

APPENDIX 8 (continued)

HIGH VARIATION IN PRODUCT MIX SCENARIO

NUMBER OF AUTOMATED GUIDED VEHICLES

SPEED OF AUTOMATED GUIDED VEHICLES



PERFORMANCE MEASURE	L0	L4
Completed parts	426	656
% of change	0%	54%
Cost (\$)	68,228	36,792
% of change	0%	-46%
Time (min)	1,235	1,514
% of change	0%	23%

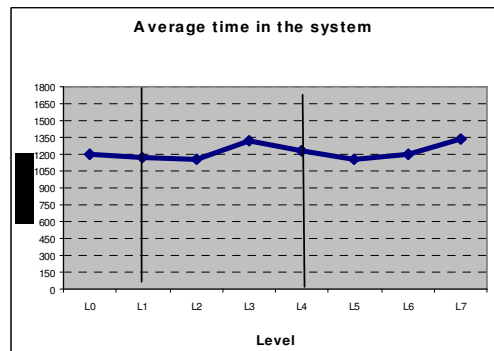
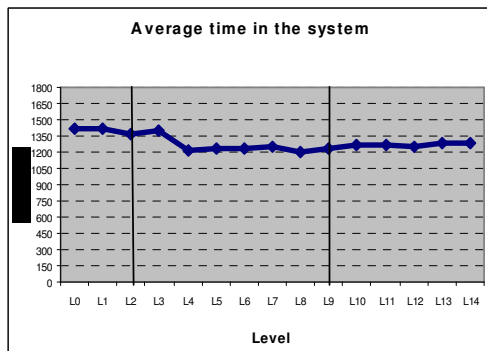
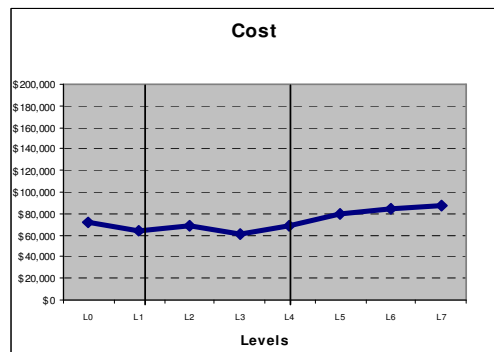
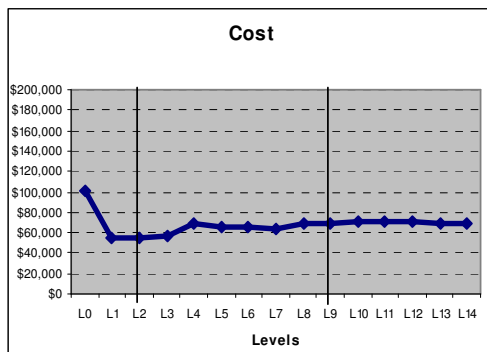
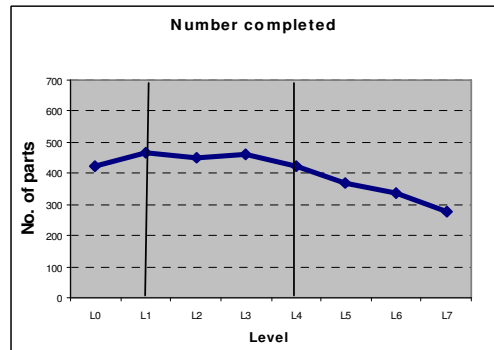
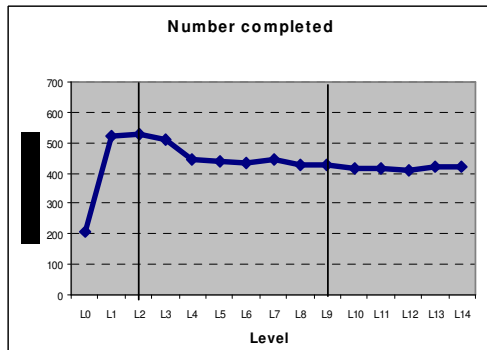
PERFORMANCE MEASURE	L1	L11
Completed parts	426	401
% of change	0%	-6%
Cost (\$)	68,228	73,468
% of change	0%	8%
Time (min)	1,235	1,174
% of change	0%	-5%

APPENDIX 8 (continued)

HIGH VARIATION IN PRODUCT MIX SCENARIO

**LOADING CAPACITY OF
AUTOMATED GUIDED VEHICLES**

**DURATION OF SET-UPS
IN MACHINES**



PERFORMANCE MEASURE	L2	L9
Completed parts	527	426
% of change	24%	0%
Cost (\$)	54,038	68,228
% of change	-21%	0%
Time (min)	1,359	1,235
% of change	10%	0%

PERFORMANCE MEASURE	L1	L4
Completed parts	468	426
% of change	10%	0%
Cost (\$)	63,903	68,228
% of change	-6%	0%
Time (min)	1,174	1,235
% of change	-5%	0%

APPENDIX 9

NUMBER OF REPLICATIONS

Having taken into consideration the large number of experimental settings that result from an experimental design involving different factors at two levels, together with the fact that, in addition to the initial model, there are 6 different simulation scenarios involved; determining a specific number of replications for each of the experimental setting would have been extremely time consuming. In stead of calculating a number of replications for every experiment within a scenario, the replications for two representative settings from each simulation scenario have been calculated. To calculate the number of replications required, a experimental setting where all the factors were at the lowest level and another setting where all the factors were at the highest level have been assumed to be representative settings. A maximum error estimate together with 95% confidence intervals have been determined for the three selected performance indicators in each of the defined simulation scenarios; those were calculated using the equations (6-1) and (6-2) described in chapter 6. Afterwards, the required number of replications for each response was calculated using equation (6-3); a desired value of error of 5 was established for all the calculations. The following tables show the initial replications together with the calculation of replications for each simulation scenario.

APPENDIX 9 (continued)

MODEL: BASELINE MODEL		ALL FACTORS AT LOW LEVEL					ALL FACTORS AT HIGH LEVEL				
		REPLICATIONS					REPLICATIONS				
Simulation Object	Performance Measure	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Work Entry Point 1	Number Entered	713.0	631.0	664.0	681.0	683.0	713.0	631.0	664.0	681.0	683.0
Work Complete 1	Number Completed	702.0	648.0	662.0	684.0	670.0	709.0	645.0	660.0	690.0	670.0
	Average Time in System	1475.6	1615.5	1533.0	1385.9	1607.2	1285.7	1410.7	1390.2	1319.1	1372.1
Simulation Total	Total Revenue on Income Statement	91260.0	84240.0	86060.0	88920.0	87100.0	92170.0	83850.0	85800.0	89700.0	87100.0
Simulation Total	Total Costs on Income Statement	38834.0	35440.2	36544.8	35521.0	37871.1	46820.3	42886.7	44125.6	43934.2	46034.1
Simulation Total	Total Profit on Income Statement	52426.0	48799.8	49515.2	53399.0	49228.9	45349.7	40963.3	41674.4	45765.8	41065.9
Operator 1	Utilization %	25.1	18.4	16.4	19.4	21.8	44.4	38.3	35.5	38.1	40.4
Operator 2	Utilization %	26.5	19.0	23.1	20.0	33.4	26.2	19.7	22.0	22.2	34.7
Operator 3	Utilization %	24.1	21.8	37.7	22.6	30.9	19.0	16.7	26.5	17.9	24.9
Operator 4	Utilization %	48.7	44.3	40.8	40.5	42.0	39.6	38.5	34.2	36.8	40.0
Operator 5	Utilization %	29.7	26.3	24.5	22.0	21.3	32.6	24.8	25.8	23.1	22.5
Operator 6	Utilization %	24.1	28.9	25.0	27.0	26.2	36.9	37.0	38.1	34.7	37.2
Work Center 1	Waiting %	78.0	80.0	81.0	78.0	79.5	79.6	79.5	81.0	77.5	79.0
	Working %	11.7	10.2	11.4	12.9	12.3	11.7	10.2	11.4	12.9	12.3
	Blocked %	2.1	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	7.0	8.8	5.8	8.0	7.1	7.0	8.8	5.8	8.0	7.1
	Change Over %	1.2	1.0	1.2	1.1	1.2	1.7	1.5	1.7	1.6	1.6
Work Center 2	Waiting %	67.8	73.0	74.7	73.5	75.6	67.1	72.3	74.2	72.9	75.7
	Working %	21.0	16.9	17.4	17.2	16.2	21.0	16.9	17.4	17.2	16.2
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	10.1	9.0	7.1	8.5	6.9	10.1	9.0	7.1	8.5	6.9
	Change Over %	1.1	1.1	0.8	0.8	1.3	1.8	1.8	1.4	1.4	1.2
Work Center 3	Waiting %	81.5	83.4	81.8	81.6	83.1	81.5	83.4	81.8	81.6	83.1
	Working %	11.6	11.6	12.5	10.8	11.7	11.6	11.6	12.5	10.8	11.7
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	6.8	5.0	5.7	7.6	5.2	6.8	5.0	5.7	7.6	5.2
	Change Over %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Work Center 4	Waiting %	80.1	80.3	76.3	79.0	79.9	77.2	77.7	74.0	76.8	78.9
	Working %	7.5	7.5	7.4	8.2	8.7	7.5	7.5	7.4	8.2	8.7
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	10.6	10.5	14.2	11.5	9.8	10.6	10.5	14.2	11.5	9.8
	Change Over %	1.7	1.7	2.1	1.3	1.6	4.7	4.3	4.4	3.5	2.7
Work Center 5	Waiting %	68.2	69.6	67.6	67.5	66.8	62.7	66.2	63.2	63.2	64.3
	Working %	12.7	11.0	12.0	13.0	12.3	12.9	10.9	12.0	12.9	12.3
	Blocked %	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0
	Stopped %	15.6	16.5	17.4	16.8	16.9	15.6	16.5	17.4	16.8	16.9
	Change Over %	3.5	2.9	2.8	2.7	3.7	8.8	6.4	7.4	7.1	6.5
Work Center 6	Waiting %	72.5	76.6	75.1	75.5	73.9	68.8	73.8	68.5	69.2	71.1
	Working %	19.9	17.2	17.8	17.0	16.8	19.8	17.2	17.8	17.1	16.7
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	3.8	3.5	3.5	3.5	5.5	3.8	3.5	3.5	3.5	5.5
	Change Over %	3.9	2.7	3.6	4.0	3.8	7.6	5.5	10.2	10.1	6.7
Work Center 7	Waiting %	79.5	81.2	80.3	78.3	78.8	77.7	79.5	77.5	76.3	76.1
	Working %	9.2	8.7	8.3	8.0	8.2	9.3	8.4	8.3	8.2	8.1
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	10.0	8.9	10.5	12.8	12.1	10.0	8.9	10.5	12.8	12.1
	Change Over %	1.3	1.1	0.9	0.9	1.0	3.0	3.2	3.7	2.7	3.7
Work Center 8	Waiting %	76.1	74.3	75.9	73.0	76.6	73.1	72.0	74.3	69.8	74.5
	Working %	8.4	6.7	7.6	7.6	6.8	8.5	6.6	7.5	7.6	6.8
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	13.3	17.3	15.1	18.0	15.7	13.3	17.3	15.1	18.0	15.7
	Change Over %	2.2	1.6	1.5	1.3	0.9	5.1	4.0	3.0	4.5	3.1
Work Center 9	Waiting %	66.8	67.2	69.5	68.2	69.7	65.8	67.4	68.8	67.8	68.0
	Working %	15.9	15.2	15.1	17.2	16.3	16.1	15.0	15.1	17.2	16.4
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	13.2	13.9	12.6	10.9	10.9	13.2	13.9	12.6	10.9	10.9
	Change Over %	4.1	3.8	2.9	3.7	3.0	4.9	3.8	3.6	4.2	4.7
Part 1 storage	Average queue size	4.5	4.7	4.3	4.5	5.0	4.5	4.7	4.3	4.5	5.0
Part 2 storage	Average queue size	4.3	4.6	4.6	4.2	4.7	4.3	4.6	4.6	4.2	4.6
Part 3 storage	Average queue size	4.5	4.8	4.4	5.0	4.4	4.5	4.8	4.4	5.0	4.4
Part 4 storage	Average queue size	4.3	4.5	4.5	4.2	4.5	4.3	4.5	4.5	4.2	4.5
Part 5 storage	Average queue size	4.6	4.6	4.2	4.4	4.4	4.6	4.6	4.2	4.4	4.4
Part 6 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 7 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 8 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 9 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 10 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 1	Average queue size	1.7	0.7	0.9	0.9	1.2	0.9	0.7	0.8	0.9	1.0
Queue for Loader 1	Average queue size	0.8	0.5	0.6	0.3	0.4	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 2	Average queue size	1.3	1.0	1.3	1.0	2.3	1.4	1.1	1.1	1.1	1.2
Queue for Loader 3	Average queue size	0.3	0.3	0.4	0.2	0.5	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 3	Average queue size	0.7	0.7	1.0	0.7	1.1	0.6	0.6	0.8	0.6	0.9
Queue for Loader 5	Average queue size	0.3	0.2	0.2	0.1	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 4	Average queue size	0.4	0.4	1.0	0.4	0.5	0.4	0.3	0.3	0.3	0.2
Queue for Loader 7	Average queue size	0.5	0.4	0.5	0.3	0.5	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 5	Average queue size	1.1	1.1	0.6	0.7	1.1	1.0	0.7	0.9	0.8	0.8
Queue for Loader 9	Average queue size	0.6	0.4	0.6	0.5	0.6	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 6	Average queue size	0.5	0.8	0.2	0.3	0.3	0.7	0.4	1.2	0.8	0.7
Queue for Loader 11	Average queue size	0.6	0.3	0.5	0.4	0.4	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 7	Average queue size	0.4	0.6	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2
Queue for loader 13	Average queue size	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 8	Average queue size	0.6	0.4	0.4	0.3	0.3	0.2	0.3	0.4	0.3	0.3
Queue for Loader 15	Average queue size	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 9	Average queue size	0.3	0.9	0.4	0.6	0.6	0.7	0.6	0.5	0.7	0.6
Queue for Shipping	Average queue size	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Baseline model; all factors at low level			
Replication	Parts	Cost	Avg. time in system
1	702	\$38,834	1,476
2	648	\$35,440	1,616
3	662	\$36,545	1,533
4	684	\$35,521	1,386
5	670	\$37,871	1,607
Confidence intervals			
Mean \bar{X}	673.2	\$36,842	1,523
S (x)	20.7	\$1,485	96
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	25.7	\$1,844	119
X - E	647.5	\$34,998	1,404
X + E	698.9	\$38,686	1,643
E* (Desired value of E)	5	5	5
Number of replications	132	680,097	2,835

Baseline model; all factors at high level			
Replication	Parts	Cost	Avg. time in system
1	709	\$46,820	1,286
2	645	\$42,887	1,411
3	660	\$44,126	1,390
4	690	\$43,934	1,319
5	670	\$46,034	1,372
Confidence intervals			
Mean \bar{X}	674.8	\$44,760	1,356
S (x)	25.2	\$1,617	52
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	31.2	\$2,008	64
X - E	643.6	\$42,752	1,291
X + E	706.0	\$46,768	1,420
E* (Desired value of E)	5	5	5
Number of replications	195	806,227	827

The no. of replications chosen for all of the experiments in this scenario is 200

APPENDIX 9 (continued)

MODEL: FREQUENT MACHINE BREAKDOWN SCENARIO		ALL FACTORS AT LOW LEVEL					ALL FACTORS AT HIGH LEVEL				
		REPLICATIONS					REPLICATIONS				
Simulation Object	Performance Measure	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Work Entry Point 1	Number Entered	653.0	629.0	652.0	642.0	705.0	626.0	670.0	659.0	647.0	716.0
Work Complete 1	Number Completed	674.0	630.0	628.0	642.0	684.0	634.0	680.0	660.0	658.0	710.0
	Average Time in System	1498.3	1548.8	1719.1	1664.5	1492.2	1643.2	1567.5	1539.1	1602.3	1594.3
Simulation Total	Total Revenue on Income Statement	87620.0	81900.0	81640.0	83460.0	88920.0	82420.0	88400.0	85800.0	85540.0	92300.0
Simulation Total	Total Costs on Income Statement	36536.4	35657.2	38461.1	37246.6	38945.7	63744.8	64958.7	64401.7	63847.5	70419.5
Simulation Total	Total Profit on Income Statement	51083.6	46242.8	43178.9	46213.4	49974.3	18675.2	23441.3	21398.3	21692.5	21880.5
Operator 1	Utilization %	17.8	25.4	21.6	19.3	19.3	53.5	46.9	45.7	49.2	50.5
Operator 2	Utilization %	33.4	26.6	30.7	31.0	32.3	29.1	31.6	30.2	39.1	36.2
Operator 3	Utilization %	27.1	29.4	28.0	27.3	30.1	22.4	32.6	38.0	23.3	30.1
Operator 4	Utilization %	47.3	40.6	52.5	46.9	51.4	52.4	49.5	48.1	46.7	54.9
Operator 5	Utilization %	26.4	27.7	29.3	25.9	29.0	36.4	35.3	35.2	39.2	38.7
Operator 6	Utilization %	29.4	26.2	31.1	33.8	28.7	48.9	50.2	45.0	47.1	58.1
Work Center 1	Waiting %	58.5	56.8	58.9	57.7	61.4	57.3	54.4	58.6	57.3	57.3
	Working %	12.3	10.4	10.7	11.9	12.2	11.2	12.6	11.6	11.0	11.9
	Blocked %	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	29.0	32.6	29.5	30.2	26.3	30.0	31.4	28.5	30.1	29.3
	Change Over %	0.2	0.2	0.2	0.2	0.2	1.5	1.6	1.4	1.6	1.5
Work Center 2	Waiting %	47.1	47.1	44.8	43.5	45.8	46.3	46.3	48.1	44.5	42.2
	Working %	15.6	17.0	19.0	16.9	19.0	16.7	17.7	17.0	18.3	19.2
	Blocked %	0.0	0.0	0.8	1.7	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	37.1	35.8	35.2	37.7	35.1	35.6	34.2	33.5	35.6	36.7
	Change Over %	0.2	0.1	0.2	0.2	0.2	1.4	1.8	1.4	1.6	1.8
Work Center 3	Waiting %	58.6	59.7	56.9	58.6	56.8	57.8	59.6	56.2	56.9	57.9
	Working %	11.6	10.9	10.0	9.8	10.8	10.8	10.9	11.7	10.1	12.5
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	29.9	29.4	33.1	31.6	32.4	31.3	29.5	32.1	33.0	29.6
	Change Over %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Work Center 4	Waiting %	54.7	58.3	52.2	56.9	55.8	54.4	45.9	52.1	53.0	49.6
	Working %	7.2	7.2	7.0	7.8	7.2	7.1	7.6	8.1	6.7	8.6
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	38.0	34.2	40.6	34.9	36.7	35.6	41.6	36.2	36.8	36.6
	Change Over %	0.1	0.2	0.2	0.4	0.3	2.8	5.0	3.6	3.6	5.2
Work Center 5	Waiting %	54.7	58.3	51.4	57.9	54.6	47.5	50.2	46.3	52.3	47.7
	Working %	12.2	10.8	11.2	12.0	12.9	11.2	12.5	12.0	11.6	12.8
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	31.8	30.2	36.2	29.1	31.2	34.3	30.6	34.6	30.1	30.4
	Change Over %	1.3	0.8	1.2	0.9	1.3	7.1	6.7	7.1	6.0	9.1
Work Center 6	Waiting %	51.5	48.9	47.5	50.1	46.5	40.8	39.6	40.0	38.1	37.3
	Working %	16.3	16.6	17.2	15.9	18.1	16.4	17.1	17.2	17.7	19.3
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	30.9	33.1	33.6	32.5	33.9	35.5	36.1	35.0	36.5	33.5
	Change Over %	1.3	1.4	1.7	1.4	1.6	7.2	7.2	7.8	7.7	9.9
Work Center 7	Waiting %	53.8	52.3	50.1	51.9	50.4	49.0	51.5	47.5	48.9	48.9
	Working %	8.2	8.7	8.9	7.7	8.7	8.6	8.7	8.1	8.9	9.1
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	37.6	38.5	40.4	39.9	40.2	37.4	36.8	41.0	37.2	37.5
	Change Over %	0.4	0.5	0.5	0.4	0.7	4.9	2.9	3.5	5.0	4.4
Work Center 8	Waiting %	52.0	52.3	50.8	52.7	52.3	48.0	47.0	50.1	52.9	47.3
	Working %	7.7	6.4	6.4	6.8	8.2	6.6	7.5	7.1	7.4	7.6
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	39.9	41.1	42.5	40.2	38.8	42.7	42.2	39.9	37.8	40.7
	Change Over %	0.4	0.3	0.3	0.2	0.6	2.7	3.3	3.0	1.9	4.5
Work Center 9	Waiting %	46.3	44.2	46.3	47.6	44.2	41.6	41.0	42.0	41.3	39.3
	Working %	16.8	15.2	15.0	16.2	16.4	15.6	17.0	15.4	15.5	16.0
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	35.7	39.6	37.4	35.2	38.5	37.8	35.9	38.1	37.2	38.5
	Change Over %	1.3	0.9	1.2	1.0	1.0	5.0	6.2	4.6	5.9	6.2
Part 1 storage	Average queue size	4.4	4.3	4.6	4.5	4.6	4.3	4.5	4.2	4.3	4.8
Part 2 storage	Average queue size	4.3	4.8	4.6	4.5	4.3	4.5	4.2	4.9	4.8	4.7
Part 3 storage	Average queue size	4.3	4.5	4.6	4.8	4.6	4.8	4.3	4.6	4.2	4.4
Part 4 storage	Average queue size	4.1	4.5	4.8	4.3	4.6	4.1	4.3	4.8	4.4	4.3
Part 5 storage	Average queue size	4.4	4.8	4.9	4.7	4.2	4.5	4.2	4.5	4.7	4.5
Part 6 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 7 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 8 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 9 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 10 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 1	Average queue size	0.9	1.3	0.9	1.1	0.8	1.2	1.2	1.0	0.9	1.4
Queue for Loader 1	Average queue size	0.2	0.1	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 2	Average queue size	1.6	1.3	1.8	1.7	1.8	1.5	1.8	1.5	1.8	2.0
Queue for Loader 3	Average queue size	0.2	0.1	0.5	0.5	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 3	Average queue size	0.9	1.0	0.9	0.8	1.1	0.8	1.4	1.2	0.8	1.1
Queue for Loader 5	Average queue size	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 4	Average queue size	0.5	0.6	0.7	0.9	0.8	0.5	0.9	0.5	0.7	0.9
Queue for Loader 7	Average queue size	0.2	0.2	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 5	Average queue size	1.1	0.6	1.5	0.9	1.3	1.4	0.7	0.9	0.7	1.7
Queue for Loader 9	Average queue size	0.3	0.2	0.4	0.4	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 6	Average queue size	0.5	0.5	0.7	0.5	0.6	1.5	1.5	1.7	1.4	1.7
Queue for Loader 11	Average queue size	0.2	0.2	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 7	Average queue size	0.3	0.2	0.7	0.4	0.5	0.4	0.3	0.4	0.4	0.5
Queue for loader 13	Average queue size	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 8	Average queue size	0.6	0.3	0.5	0.6	0.7	0.7	0.7	0.4	0.4	0.8
Queue for Loader 15	Average queue size	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 9	Average queue size	0.7	0.6	0.8	1.0	0.6	1.3	1.7	1.2	1.7	1.8
Queue for Shipping	Average queue size	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Machine breakdowns; all factors at low level			
Replication	Parts	Cost	Avg. time in system
46	674	\$36,536	1,498
47	630	\$35,657	1,549
48	628	\$38,461	1,719
49	642	\$37,247	1,664
50	684	\$38,946	1,492
Confidence intervals			
Mean \bar{X}	651.6	\$37,369	1,585
S (x)	25.8	\$1,353	102
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	32.1	\$1,679	127
X - E	619.5	\$35,690	1,458
X + E	683.7	\$39,048	1,711
E* (Desired value of E)	5	5	5
Number of replications	206	563,863	3,218

Machine breakdowns; all factors at high level			
Replication	Parts	Cost	Avg. time in system
1	634.0	\$63,745	1,983
2	680.0	\$64,959	1,985
3	660.0	\$64,402	1,862
4	658.0	\$63,847	2,199
5	710.0	\$70,420	2,164
Confidence intervals			
Mean \bar{X}	668.4	\$65,474	1,643
S (x)	28.4	\$2,807	1,568
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	35.3	\$3,484	1,539
X - E	633.1	\$61,990	1,602
X + E	703.7	\$68,959	1,594
E* (Desired value of E)	5	5	5
Number of replications	249	2,428,163	473,786

The no. of replications chosen for all of the experiments in this scenario is 250

APPENDIX 9 (continued)

MODEL: FREQUENT OPERATOR UNAVAILABILITY SCENARIO		ALL FACTORS AT LOW LEVEL					ALL FACTORS AT HIGH LEVEL				
		REPLICATIONS					REPLICATIONS				
Simulation Object	Performance Measure	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Work Entry Point 1	Number Entered	626.0	670.0	681.0	683.0	681.0	626.0	670.0	659.0	647.0	716.0
Work Complete 1	Number Completed	631.0	676.0	682.0	665.0	665.0	637.0	678.0	661.0	644.0	700.0
	Average Time in System	1471.9	1435.2	1387.0	1461.3	1429.4	1371.5	1352.7	1361.3	1416.8	1344.6
Simulation Total	Total Revenue on Income Statement	82030.0	87880.0	88660.0	86450.0	86450.0	82810.0	88140.0	85930.0	83720.0	91000.0
Simulation Total	Total Costs on Income Statement	34490.1	35787.9	35630.0	36578.6	36369.2	56897.6	57723.9	60036.9	57048.3	62440.0
Simulation Total	Total Profit on Income Statement	47539.9	52092.1	53030.0	49871.4	50080.8	25912.4	30416.1	25893.1	26671.7	28560.0
Operator 1	Utilization %	12.4	17.8	16.0	24.0	16.7	31.9	32.1	41.0	31.0	35.4
Operator 2	Utilization %	24.7	29.6	24.0	25.5	29.2	34.5	26.2	25.3	19.3	21.9
Operator 3	Utilization %	26.2	23.9	23.4	22.1	23.8	33.9	35.0	38.8	39.2	41.2
Operator 4	Utilization %	39.8	42.2	39.5	45.5	42.4	40.2	37.7	39.3	35.8	40.2
Operator 5	Utilization %	24.1	20.7	26.6	26.9	31.2	25.0	22.6	33.7	26.4	33.2
Operator 6	Utilization %	34.1	30.0	24.7	21.1	22.2	38.3	39.1	36.7	33.6	40.4
Work Center 1	Waiting %	82.1	79.1	78.7	81.5	79.4	81.0	77.9	78.8	79.4	78.9
	Working %	11.2	12.6	12.9	11.1	11.1	11.2	12.6	11.6	11.2	11.7
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	6.3	7.9	8.0	7.1	9.1	6.3	7.9	8.2	7.8	7.9
	Change Over %	0.4	0.4	0.4	0.4	0.5	1.5	1.6	1.4	1.6	1.5
Work Center 2	Waiting %	73.6	72.4	74.0	76.5	69.6	72.6	71.2	72.0	72.8	69.8
	Working %	16.3	17.7	17.1	16.2	19.5	16.3	17.7	17.2	18.3	19.3
	Blocked %	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	9.6	9.3	8.5	6.9	10.4	9.6	9.3	9.4	7.3	9.0
	Change Over %	0.5	0.6	0.4	0.3	0.6	1.4	1.8	1.4	1.6	1.9
Work Center 3	Waiting %	83.1	81.8	81.6	83.1	81.7	83.1	81.8	81.2	82.1	79.2
	Working %	10.8	10.9	10.8	11.7	11.7	10.8	10.9	11.7	10.1	11.8
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	6.0	7.3	7.6	5.2	6.6	6.0	7.3	7.2	7.9	9.0
	Change Over %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Work Center 4	Waiting %	81.0	79.2	79.7	81.3	78.4	79.4	76.8	73.8	77.0	75.2
	Working %	7.1	7.6	8.2	8.1	7.8	7.1	7.6	8.1	6.7	8.4
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	11.1	12.3	11.5	9.8	13.1	11.1	12.3	14.3	12.9	11.5
	Change Over %	0.7	0.9	0.7	0.8	0.7	2.3	3.3	3.8	3.4	4.9
Work Center 5	Waiting %	70.3	68.4	68.2	69.4	69.2	66.4	63.5	64.0	65.8	59.3
	Working %	11.3	12.5	12.9	11.5	11.9	11.2	12.5	12.1	11.9	12.6
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	16.6	16.7	16.8	16.9	16.8	16.6	16.7	17.8	16.1	18.8
	Change Over %	1.8	2.4	2.1	2.2	2.1	5.8	7.3	6.2	6.2	9.2
Work Center 6	Waiting %	77.5	77.9	77.4	75.6	75.8	71.7	72.6	69.5	72.8	68.8
	Working %	15.7	17.1	16.9	17.1	18.7	16.2	17.0	17.4	17.0	18.8
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	5.3	3.0	3.5	5.5	3.4	5.3	3.0	5.1	5.2	4.3
	Change Over %	1.4	2.1	2.2	1.8	2.0	6.8	7.3	7.9	5.0	8.2
Work Center 7	Waiting %	80.8	78.5	78.7	79.0	79.6	75.7	76.6	77.9	77.7	76.8
	Working %	8.0	8.8	8.1	8.4	8.9	8.2	8.8	8.1	8.3	8.9
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	10.6	12.2	12.8	12.1	10.8	10.6	12.2	11.4	11.3	11.5
	Change Over %	0.6	0.6	0.4	0.5	0.6	5.5	2.4	2.7	2.7	2.8
Work Center 8	Waiting %	76.2	76.2	73.6	76.9	76.2	74.8	73.3	74.9	73.9	75.3
	Working %	6.7	7.5	7.6	6.6	7.2	6.6	7.5	7.2	7.6	7.5
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	16.5	15.4	18.0	15.7	15.9	16.5	15.4	15.3	16.4	13.5
	Change Over %	0.6	1.0	0.8	0.7	0.6	2.1	3.9	2.6	2.0	3.7
Work Center 9	Waiting %	73.0	68.4	70.2	72.0	71.3	71.6	65.3	68.7	67.8	67.5
	Working %	15.6	16.9	17.1	15.4	14.8	15.6	17.0	15.4	15.4	16.0
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	9.5	12.2	10.9	10.9	12.2	9.5	12.2	11.6	12.6	10.9
	Change Over %	2.0	2.5	1.9	1.7	1.7	3.4	5.5	4.4	4.2	5.6
Part 1 storage	Average queue size	4.3	4.5	4.5	5.0	4.4	4.3	4.5	4.2	4.3	4.8
Part 2 storage	Average queue size	4.5	4.2	4.2	4.6	4.1	4.5	4.2	4.9	4.8	4.7
Part 3 storage	Average queue size	4.8	4.3	5.0	4.4	4.6	4.8	4.3	4.6	4.2	4.4
Part 4 storage	Average queue size	4.1	4.3	4.2	4.5	4.2	4.1	4.3	4.8	4.4	4.3
Part 5 storage	Average queue size	4.5	4.2	4.4	4.4	4.5	4.5	4.2	4.5	4.7	4.5
Part 6 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 7 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 8 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 9 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 10 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 1	Average queue size	0.6	0.8	0.8	1.4	0.7	0.7	0.8	0.8	0.8	0.9
Queue for Loader 1	Average queue size	0.2	0.2	0.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 2	Average queue size	1.1	1.5	1.2	1.0	1.5	1.0	1.2	1.1	1.1	1.3
Queue for Loader 3	Average queue size	0.1	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 3	Average queue size	0.6	0.7	0.7	0.7	0.7	0.6	0.6	0.7	1.3	1.1
Queue for Loader 5	Average queue size	0.1	0.1	0.1	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 4	Average queue size	0.4	0.4	0.4	0.4	0.3	0.2	0.4	0.4	0.3	0.5
Queue for Loader 7	Average queue size	0.2	0.3	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 5	Average queue size	0.8	0.9	0.8	0.8	1.0	0.7	0.7	0.7	0.6	1.0
Queue for Loader 9	Average queue size	0.3	0.3	0.3	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 6	Average queue size	0.4	0.3	0.3	0.9	1.0	0.7	0.7	0.9	0.4	0.8
Queue for Loader 11	Average queue size	0.3	0.3	0.3	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 7	Average queue size	0.1	0.3	0.4	0.6	0.5	0.2	0.2	0.2	0.2	0.1
Queue for loader 13	Average queue size	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 8	Average queue size	0.3	0.3	0.4	0.3	0.4	0.3	0.2	0.4	0.2	0.4
Queue for Loader 15	Average queue size	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 9	Average queue size	1.1	0.8	0.6	0.3	0.5	0.4	1.1	0.5	0.7	0.9
Queue for Shipping	Average queue size	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Operator unavailability; all factors at low level				
Replication	Parts	Cost	Avg. time in system	
1	631	\$34,490	1,472	
2	676	\$35,788	1,435	
9	682	\$35,630	1,387	
10	665	\$36,579	1,461	
11	665	\$36,369	1,429	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		663.8	\$35,771	1,437
S (x)		19.7	\$817	33
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		24.5	\$1,014	41
X - E		639.3	\$34,757	1,396
X + E		688.3	\$36,786	1,478
E* (Desired value of E)		5	5	5
Number of replications	120	205,810	336	

Operator unavailability; all factors at high level				
Replication	Parts	Cost	Avg. time in system	
1	637	\$56,898	1,371	
2	678	\$57,724	1,353	
3	661	\$60,037	1,361	
4	644	\$57,048	1,417	
5	700	\$62,440	1,345	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		664.0	\$58,829	1,369
S (x)		25.6	\$2,378	28
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		31.8	\$2,952	35
X - E		632.2	\$55,877	1,334
X + E		695.8	\$61,782	1,405
E* (Desired value of E)		5	5	5
Number of replications	203	1,743,241	247	

The no. of replications chosen for all of the experiments in this scenario is 250

APPENDIX 9 (continued)

MODEL: IRREGULAR PATTERN OF RAW MATERIAL ARRIVALS SCENARIO		ALL FACTORS AT LOW LEVEL					ALL FACTORS AT HIGH LEVEL				
		REPLICATIONS					REPLICATIONS				
Simulation Object	Performance Measure	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Work Entry Point 1	Number Entered	807.0	735.0	741.0	757.0	780.0	742.0	812.0	782.0	796.0	865.0
Work Complete 1	Number Completed	799.0	713.0	746.0	769.0	778.0	747.0	796.0	780.0	796.0	840.0
	Average Time in System	1266.2	1493.0	1385.5	1332.6	1317.4	1326.1	1368.9	1284.5	1282.5	1300.0
Simulation Total	Total Revenue on Income Statement	103870.0	92690.0	96980.0	99970.0	101140.0	97110.0	103480.0	101400.0	103480.0	109200.0
Simulation Total	Total Costs on Income Statement	40276.9	38787.3	38500.8	38755.3	40289.9	66059.8	71857.7	66760.6	66841.7	75014.5
Simulation Total	Total Profit on Income Statement	63593.1	53902.7	58479.2	61214.7	60850.1	31050.2	31622.3	34639.4	36638.3	34185.5
Operator 1	Utilization %	22.2	23.4	21.5	18.5	23.5	50.3	45.2	40.6	42.1	50.2
Operator 2	Utilization %	25.5	23.6	24.4	22.2	29.1	28.5	27.9	26.9	25.0	37.7
Operator 3	Utilization %	28.2	22.1	23.4	31.3	23.7	36.4	40.4	41.2	37.2	50.6
Operator 4	Utilization %	43.4	44.7	41.2	43.0	45.9	41.4	46.0	39.2	38.6	47.5
Operator 5	Utilization %	23.1	22.0	22.2	21.8	27.8	42.6	48.0	36.4	38.9	46.8
Operator 6	Utilization %	28.1	29.1	29.5	23.9	24.4	37.9	45.8	43.0	42.7	46.8
Work Center 1	Waiting %	77.2	78.2	78.0	78.6	78.0	73.3	72.4	74.9	73.4	72.1
	Working %	14.5	13.1	15.0	14.2	13.8	12.2	13.4	13.9	14.5	15.4
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	7.9	7.5	6.0	6.4	7.7	7.0	8.8	5.8	8.0	7.1
	Change Over %	0.4	1.2	1.0	0.8	0.5	7.5	5.4	5.4	4.1	5.4
Work Center 2	Waiting %	68.9	67.6	72.7	69.1	66.6	60.7	59.8	67.8	67.0	67.5
	Working %	20.7	20.4	18.2	19.2	22.9	21.4	21.9	19.6	20.2	20.7
	Blocked %	0.0	0.1	0.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0
	Stopped %	9.9	11.0	7.5	11.2	9.4	10.1	9.0	7.1	8.5	6.9
	Change Over %	0.5	0.8	1.0	0.5	0.9	7.7	9.4	5.5	4.2	4.9
Work Center 3	Waiting %	80.2	82.9	84.0	81.1	85.4	80.2	80.0	81.0	79.1	79.8
	Working %	13.3	11.7	11.2	12.4	10.3	12.9	15.0	13.3	13.3	15.0
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	6.5	5.4	4.8	6.4	4.2	6.8	5.0	5.7	7.6	5.2
	Change Over %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Work Center 4	Waiting %	77.0	78.2	78.4	78.6	79.1	77.8	74.8	71.3	72.9	73.3
	Working %	9.7	8.3	9.1	9.0	7.8	7.8	9.4	8.5	9.8	10.5
	Blocked %	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	Stopped %	12.7	13.2	12.1	12.1	12.7	10.6	10.5	14.2	11.5	9.8
	Change Over %	0.5	0.3	0.4	0.2	0.2	3.8	5.3	5.9	5.9	6.4
Work Center 5	Waiting %	65.7	63.3	68.2	70.3	64.0	57.9	55.8	56.5	52.6	52.4
	Working %	14.7	13.3	14.2	13.9	14.5	13.2	13.8	14.4	14.9	15.6
	Blocked %	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	18.0	21.3	16.1	13.9	19.8	15.6	16.5	17.4	16.8	16.9
	Change Over %	1.6	2.1	1.5	1.9	1.6	13.3	13.8	11.6	15.7	15.0
Work Center 6	Waiting %	72.8	75.9	77.1	76.8	74.2	59.6	59.1	65.9	62.8	57.5
	Working %	20.3	18.6	17.5	18.7	19.8	20.7	21.6	20.0	19.7	21.4
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	5.2	4.0	3.6	3.0	4.3	3.8	3.5	3.5	3.5	5.5
	Change Over %	1.7	1.6	1.9	1.5	1.7	15.9	15.9	10.6	14.0	15.6
Work Center 7	Waiting %	79.2	77.6	78.8	78.5	77.5	74.2	74.4	76.3	73.8	74.5
	Working %	9.9	9.0	8.6	9.7	9.7	9.8	10.9	9.5	9.1	10.0
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	10.5	13.1	12.1	11.2	12.3	10.0	8.9	10.5	12.8	12.1
	Change Over %	0.4	0.4	0.4	0.6	0.5	6.0	5.8	3.8	4.3	3.4
Work Center 8	Waiting %	76.1	76.5	73.0	76.6	75.5	73.9	67.5	71.2	66.2	67.3
	Working %	8.5	7.6	8.0	8.2	9.2	8.6	8.3	8.9	8.6	9.1
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	14.9	15.5	18.6	14.7	14.7	13.3	17.3	15.1	18.0	15.7
	Change Over %	0.5	0.4	0.4	0.5	0.6	4.2	6.9	4.8	7.2	8.0
Work Center 9	Waiting %	67.7	69.7	67.4	68.6	66.7	59.1	56.2	58.6	61.5	59.2
	Working %	19.5	17.4	19.5	19.4	19.7	17.0	18.7	18.6	19.5	20.3
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	11.7	11.3	11.9	10.6	12.2	13.2	13.9	12.6	10.9	10.9
	Change Over %	1.1	1.5	1.2	1.4	1.4	10.7	11.2	10.2	8.1	9.6
Part 1 storage	Average queue size	4.6	4.2	4.2	5.1	3.9	4.4	5.1	4.1	4.0	4.8
Part 2 storage	Average queue size	4.7	4.5	4.2	4.4	4.4	4.1	4.8	4.6	4.7	4.7
Part 3 storage	Average queue size	4.4	4.9	4.5	4.5	4.8	4.3	4.6	4.6	4.6	4.2
Part 4 storage	Average queue size	4.5	4.5	4.3	3.9	4.0	4.3	4.4	4.7	4.2	4.7
Part 5 storage	Average queue size	3.9	4.4	5.2	4.4	4.6	4.6	4.7	4.7	4.4	4.4
Part 6 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 7 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 8 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 9 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 10 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 1	Average queue size	0.9	0.9	1.0	0.9	1.2	1.4	1.3	1.3	1.2	1.4
Queue for Loader 1	Average queue size	0.3	0.5	0.4	0.3	0.4	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 2	Average queue size	1.3	1.3	1.2	1.1	1.5	2.1	2.4	1.6	1.5	1.7
Queue for Loader 3	Average queue size	0.3	0.6	0.4	0.3	0.4	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 3	Average queue size	0.9	0.7	0.7	1.1	0.6	0.7	0.8	0.9	0.8	1.4
Queue for Loader 5	Average queue size	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 4	Average queue size	0.7	0.5	0.7	1.2	0.5	0.3	0.4	0.7	0.7	0.9
Queue for Loader 7	Average queue size	0.4	0.6	0.7	0.4	0.5	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 5	Average queue size	0.7	1.3	0.8	0.9	1.4	1.3	1.3	1.3	2.0	1.7
Queue for Loader 9	Average queue size	0.6	0.7	0.7	0.5	0.6	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 6	Average queue size	0.2	0.2	0.2	0.3	0.5	1.2	1.2	0.7	1.2	1.4
Queue for Loader 11	Average queue size	0.4	0.5	0.7	0.4	0.6	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 7	Average queue size	0.4	0.7	0.3	0.3	0.6	0.2	0.3	0.1	0.2	0.2
Queue for loader 13	Average queue size	0.1	0.2	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 8	Average queue size	0.4	0.5	0.4	0.4	0.5	0.2	0.3	0.3	0.2	0.3
Queue for Loader 15	Average queue size	0.1	0.2	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 9	Average queue size	0.6	0.7	1.0	0.4	0.5	0.9	1.4	1.2	0.8	1.2
Queue for Shipping	Average queue size	0.2	0.3	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.1

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Irregular arrivals; all factors at low level				
Replication	Parts	Cost	Avg. time in system	
21	799.0	\$40,277	1,266	
22	713.0	\$38,787	1,493	
28	746.0	\$38,501	1,385	
29	769.0	\$38,755	1,333	
34	778.0	\$40,290	1,317	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		761.0	\$39,322	1,359
S (x)		32.9	\$885	86
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		40.8	\$1,098	107
X - E		720.2	\$38,224	1,252
X + E		801.8	\$40,420	1,466
E* (Desired value of E)		5	5	5
Number of replications	333	241,196	2,287	

Irregular arrivals; all factors at high level				
Replication	Parts	Cost	Avg. time in system	
6	747.0	\$66,060	1,326	
7	796.0	\$71,858	1,369	
8	780.0	\$66,761	1,285	
9	796.0	\$66,842	1,282	
10	840.0	\$75,015	1,300	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		791.8	\$69,307	1,312
S (x)		33.6	\$3,943	36
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		41.7	\$4,895	45
X - E		750.1	\$64,412	1,268
X + E		833.5	\$74,202	1,357
E* (Desired value of E)		5	5	5
Number of replications	347	4,792,257	401	

The no. of replications chosen for all of the experiments in this scenario is 350

APPENDIX 9 (continued)

MODEL: INCREASED ARRIVALS OF RAW MATERIAL SCENARIO		ALL FACTORS AT LOW LEVEL					ALL FACTORS AT HIGH LEVEL				
		REPLICATIONS					REPLICATIONS				
		R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Simulation Object	Performance Measure										
Work Entry Point 1	Number Entered	1051.0	992.0	1015.0	981.0	972.0	1017.0	1008.0	1005.0	1037.0	1046.0
Work Complete 1	Number Completed	1039.0	998.0	1006.0	962.0	988.0	1021.0	1000.0	1010.0	1039.0	1027.0
	Average Time in System	1114.1	1086.9	1084.2	1231.1	1054.6	1091.3	1092.7	1051.4	1034.5	1062.7
Simulation Total	Total Revenue on Income Statement	135070.0	129740.0	130780.0	125060.0	128440.0	132730.0	130000.0	131300.0	135070.0	133510.0
Simulation Total	Total Costs on Income Statement	51156.3	47653.4	48723.3	49121.2	46165.9	79435.7	77887.7	76748.3	77322.1	80051.6
Simulation Total	Total Profit on Income Statement	83913.7	82086.6	82056.7	75938.8	82274.1	53294.3	52112.3	54551.7	57747.9	53458.4
Operator 1	Utilization %	29.0	24.7	24.5	28.8	21.5	54.8	49.8	48.8	51.2	51.5
Operator 2	Utilization %	31.5	31.9	35.3	29.8	26.2	30.3	26.6	29.8	29.5	37.1
Operator 3	Utilization %	39.3	31.8	34.6	28.6	35.1	47.6	47.3	51.3	46.6	55.1
Operator 4	Utilization %	58.4	52.8	53.3	55.7	50.0	55.6	53.4	51.0	50.0	52.6
Operator 5	Utilization %	31.0	33.3	29.6	30.8	29.1	39.5	39.6	37.8	37.0	36.4
Operator 6	Utilization %	34.5	27.5	32.1	37.6	27.9	52.6	53.9	54.3	50.7	53.7
Work Center 1	Waiting %	74.4	74.6	73.0	73.9	75.7	73.7	72.8	74.0	71.3	71.9
	Working %	18.9	17.1	18.8	18.0	17.1	16.9	16.2	17.6	18.4	18.4
	Blocked %	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	6.4	8.0	7.9	7.5	6.9	7.0	8.8	5.8	8.0	7.1
	Change Over %	0.3	0.3	0.3	0.5	0.3	2.5	2.2	2.5	2.4	2.6
Work Center 2	Waiting %	63.2	60.2	64.1	62.8	65.3	58.9	60.5	64.1	62.0	63.6
	Working %	27.1	27.1	25.7	25.9	24.3	28.5	27.8	26.6	26.9	27.2
	Blocked %	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	8.5	12.4	9.9	11.0	10.2	10.1	9.0	7.1	8.5	6.9
	Change Over %	0.3	0.3	0.3	0.3	0.2	2.6	2.7	2.2	2.5	2.2
Work Center 3	Waiting %	76.9	77.6	76.8	79.5	75.7	75.9	77.0	76.8	74.9	76.4
	Working %	17.7	16.7	16.7	15.1	18.3	17.3	18.0	17.5	17.5	18.4
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	5.4	5.7	6.5	5.4	6.0	6.8	5.0	5.7	7.6	5.2
	Change Over %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Work Center 4	Waiting %	75.3	75.5	74.0	75.3	76.1	71.8	70.6	67.4	70.5	71.8
	Working %	12.3	11.3	12.5	11.1	11.8	10.8	11.7	11.5	12.4	12.6
	Blocked %	0.4	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	11.5	12.9	12.7	13.2	11.8	10.6	10.5	14.2	11.5	9.8
	Change Over %	0.4	0.4	0.7	0.3	0.4	6.7	7.2	6.9	5.5	5.8
Work Center 5	Waiting %	63.3	63.2	62.0	59.0	63.1	54.2	54.9	54.1	52.0	52.2
	Working %	18.8	18.3	18.4	17.6	17.6	18.1	17.6	18.5	19.3	18.6
	Blocked %	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	15.6	16.3	18.0	21.3	17.1	15.6	16.5	17.4	16.8	16.9
	Change Over %	2.3	2.1	1.6	2.0	2.1	12.1	11.0	10.0	11.9	12.3
Work Center 6	Waiting %	66.2	67.4	66.7	69.2	68.0	52.7	54.5	56.0	52.7	55.2
	Working %	26.3	26.7	25.3	24.6	25.6	27.7	27.4	26.4	27.0	26.4
	Blocked %	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	5.3	3.6	5.2	4.0	4.6	3.8	3.5	3.5	3.5	5.5
	Change Over %	2.3	2.3	2.8	1.9	1.8	15.8	14.7	14.1	16.8	12.9
Work Center 7	Waiting %	74.5	76.5	75.9	74.2	78.4	69.9	71.8	70.0	68.7	69.5
	Working %	13.0	12.5	12.6	12.2	12.3	13.5	13.4	12.6	12.5	13.0
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	11.7	10.3	10.5	13.1	8.5	10.0	8.9	10.5	12.8	12.1
	Change Over %	0.8	0.6	1.0	0.5	0.7	6.6	6.0	7.0	6.0	5.4
Work Center 8	Waiting %	75.4	74.4	74.1	73.6	75.8	67.1	65.9	68.9	62.8	67.1
	Working %	10.9	11.3	10.5	10.3	10.5	11.7	10.5	11.3	11.4	10.8
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	13.0	13.8	14.9	15.5	13.4	13.3	17.3	15.1	18.0	15.7
	Change Over %	0.7	0.4	0.5	0.7	0.3	8.0	6.3	4.7	7.8	6.3
Work Center 9	Waiting %	58.4	63.9	61.5	63.5	63.5	52.7	53.7	54.8	57.4	55.8
	Working %	25.0	23.2	25.0	23.5	23.3	23.8	23.1	23.7	24.6	25.1
	Blocked %	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stopped %	14.9	11.3	11.7	11.3	11.8	13.2	13.9	12.6	10.9	10.9
	Change Over %	1.7	1.6	1.8	1.7	1.4	10.3	9.3	8.9	7.2	8.1
Part 1 storage	Average queue size	4.3	4.6	4.6	4.4	4.5	4.5	4.6	4.1	4.4	4.9
Part 2 storage	Average queue size	4.3	4.6	4.3	4.6	4.5	4.2	4.7	4.5	4.4	4.3
Part 3 storage	Average queue size	4.9	4.3	4.7	4.8	4.6	4.7	4.7	4.2	4.8	4.3
Part 4 storage	Average queue size	4.0	4.4	4.3	4.4	4.6	4.3	4.1	4.6	4.2	4.6
Part 5 storage	Average queue size	4.6	4.2	4.2	4.6	4.4	4.6	4.5	4.2	4.6	4.6
Part 6 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 7 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 8 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 9 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Part 10 storage	Average queue size	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 1	Average queue size	1.5	1.3	1.1	1.7	1.0	1.2	1.1	1.2	1.3	1.3
Queue for Loader 1	Average queue size	0.6	0.4	0.4	0.8	0.4	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 2	Average queue size	1.7	1.7	1.9	1.6	1.3	1.8	1.8	1.7	1.8	1.8
Queue for Loader 3	Average queue size	0.6	0.4	0.4	0.6	0.3	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 3	Average queue size	1.3	0.9	1.0	0.9	1.1	1.0	1.0	1.3	0.9	1.3
Queue for Loader 5	Average queue size	0.2	0.2	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 4	Average queue size	1.2	0.5	0.7	0.7	0.5	0.7	0.7	0.9	0.4	0.7
Queue for Loader 7	Average queue size	0.6	0.5	0.6	0.6	0.4	0.0	0.0	0.0	0.0	0.1
Queue for Work Center 5	Average queue size	1.2	1.1	1.0	1.8	0.9	1.8	1.3	1.3	1.2	1.8
Queue for Loader 9	Average queue size	0.8	0.6	0.6	1.1	0.5	0.0	0.0	0.0	0.1	0.0
Queue for Work Center 6	Average queue size	0.4	0.6	0.5	0.6	0.3	1.8	1.6	1.2	2.0	1.4
Queue for Loader 11	Average queue size	0.6	0.5	0.5	0.8	0.5	0.1	0.1	0.1	0.1	0.1
Queue for Work Center 7	Average queue size	0.4	0.2	0.4	0.6	0.2	0.3	0.3	0.3	0.3	0.2
Queue for loader 13	Average queue size	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 8	Average queue size	0.6	0.5	0.5	0.6	0.3	0.6	0.4	0.5	0.5	0.6
Queue for Loader 15	Average queue size	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Queue for Work Center 9	Average queue size	0.7	0.4	0.6	1.1	0.5	1.6	1.7	1.3	0.9	1.2
Queue for Shipping	Average queue size	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Increased arrivals; all factors at low level				
Replication	Parts	Cost	Avg. time in system	
16	1039.0	\$51,156	1,114	
17	998.0	\$47,653	1,087	
21	1006.0	\$48,723	1,084	
22	962.0	\$49,121	1,231	
23	988.0	\$46,166	1,055	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		998.6	\$48,564	1,114
S (x)		28.0	\$1,846	69
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		34.8	\$2,292	85
X - E		963.8	\$46,272	1,029
X + E		1033.4	\$50,856	1,199
E* (Desired value of E)		5	5	5
Number of replications	242	1,050,803	1,453	

Increased arrivals; all factors at high level				
Replication	Parts	Cost	Avg. time in system	
6	1021	\$79,436	1,091	
7	1000	\$77,888	1,093	
8	1010	\$76,748	1,051	
9	1039	\$77,322	1,035	
10	1027	\$80,052	1,063	
Confidence intervals		Parts	Cost	Avg. time in system
Mean \bar{X}		1019.4	\$78,289	1,067
S (x)		15.1	\$1,405	25
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$		18.7	\$1,744	31
X - E		1000.7	\$76,545	1,035
X + E		1038.1	\$80,033	1,098
E* (Desired value of E)		5	5	5
Number of replications	70	608,137	198	

The no. of replications chosen for all of the experiments in this scenario is 250

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

Product variety; all factors at low level				
Replication	Parts	Cost	Avg. time in system	
	30	663	\$43,424	2,507
	31	652	\$43,612	2,620
	32	728	\$44,376	2,390
	33	648	\$42,854	2,450
	34	658	\$42,772	2,560
Confidence intervals				
Mean \bar{X}	669.8	\$43,408	2,505	
S (x)	33.0	\$650	90	
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	41.0	\$807	112	
X - E	628.8	\$42,600	2,393	
X + E	710.8	\$44,215	2,617	
E* (Desired value of E)	5	5	5	
Number of replications	336	130,302	2,506	

Product variety; all factors at high level				
Replication	Parts	Cost	Avg. time in system	
	1	644	\$63,222	2,480
	2	671	\$66,548	2,580
	3	687	\$66,102	2,463
	4	633	\$64,368	2,482
	5	704	\$68,682	2,410
Confidence intervals				
Mean \bar{X}	667.8	\$65,784	2,483	
S (x)	29.4	\$2,101	61	
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	36.5	\$2,608	76	
X - E	631.3	\$63,176	2,407	
X + E	704.3	\$68,392	2,559	
E* (Desired value of E)	5	5	5	
Number of replications	267	1,360,182	1,159	

The no. of replications chosen for all of the experiments in this scenario is 350

APPENDIX 9 (continued)

NUMBER OF REPLICATIONS

High variation in product mix; all factors at low level			
Replication	Parts	Cost	Avg. time in system
2	670.0	\$35,628	1,451
3	672.0	\$34,693	1,378
4	642.0	\$34,188	1,357
5	692.0	\$38,112	1,388
7	632.0	\$32,739	1,267
Confidence intervals			
Mean \bar{X}	661.6	\$35,072	1,368
S (x)	24.3	\$1,995	66
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	30.2	\$2,477	83
X - E	631.4	\$32,595	1,286
X + E	691.8	\$37,549	1,451
E* (Desired value of E)	5	5	5
Number of replications	182	1,226,921	1,362

High variation in product mix; all factors at high level			
Replication	Parts	Cost	Avg. time in system
1	649	\$46,334	1,457
2	670	\$47,679	1,338
3	668	\$45,995	1,288
4	631	\$45,402	1,245
5	700	\$50,045	1,163
Confidence intervals			
Mean \bar{X}	663.6	\$47,091	1,298
S (x)	25.8	\$1,850	110
$E = t_{1-\alpha/2, n-1} S(x) / \sqrt{n}$	32.0	\$2,297	136
X - E	631.6	\$44,794	1,162
X + E	695.6	\$49,388	1,434
E* (Desired value of E)	5	5	5
Number of replications	205	1,055,435	3,704

The no. of replications chosen for all of the experiments in this scenario is 250

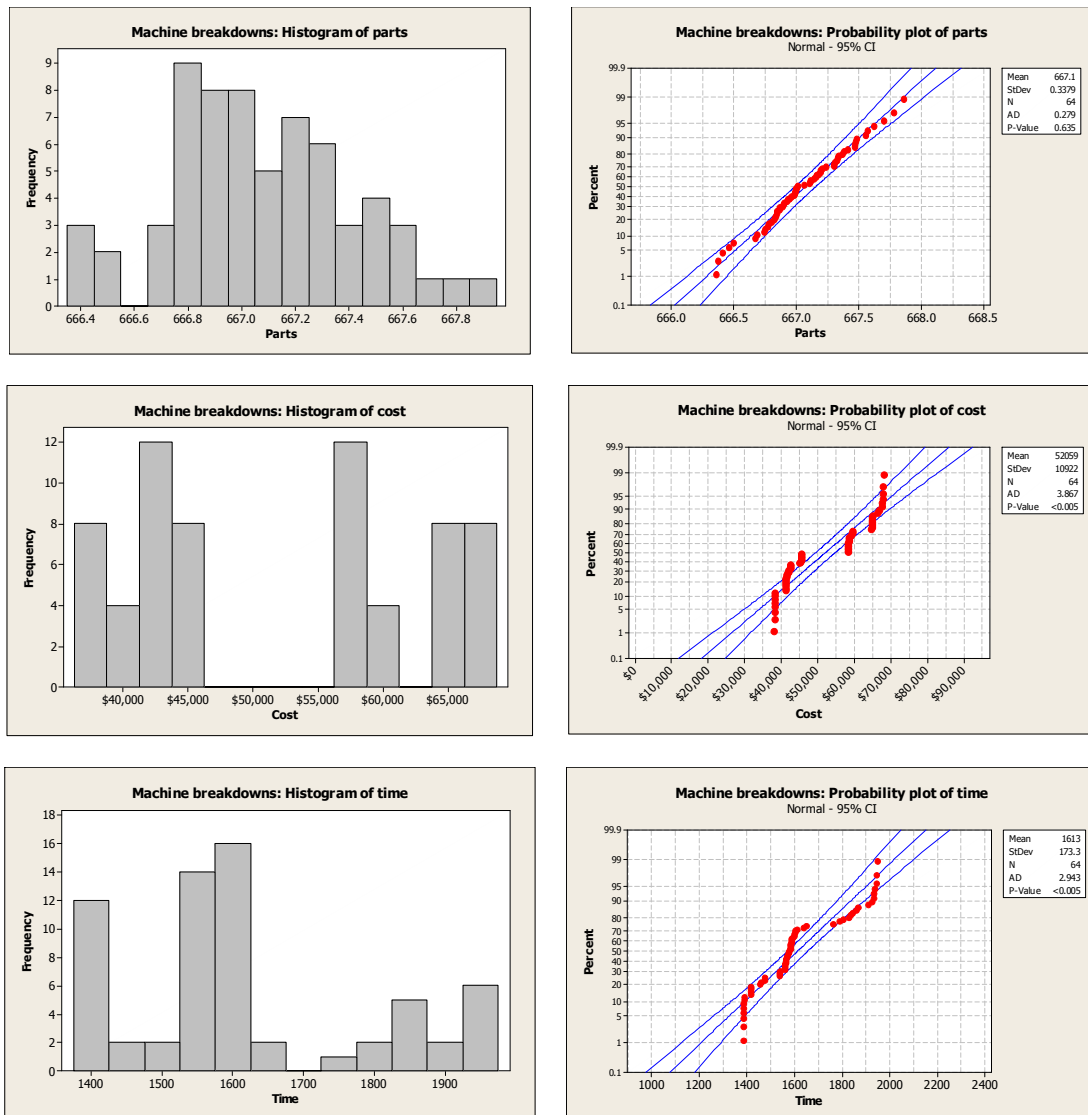
APPENDIX 9 (continued)

Note from the calculation tables above that the number of replications required for time and costs indicators is significantly larger than the number of replications required for throughput indicator. This is due to the large variation between the results of each replication in terms of those indicators. Given that the number of replications required for cost and time indicators is prohibitive compared to those required for throughput; it was decided to consider only the replications required for the throughput indicator. This means that throughput would be the primary performance indicator since it is the only indicator that has been replicated enough to guarantee statistical reliability; the other two indicator would be considered either as supportive or complimentary without any statistical reliability. From the each of the two settings considered in every experimental scenario, the setting requiring the largest number of replications has been selected as the reference point to determine the minimum number of replications for that specific simulation scenario; this means that all the possible factors combinations within that scenario would have exactly the same number of replications. Note from the tables above that even though calculation tables have provided with a minimum number of required replications a slightly larger number of replications has been set in every scenario to provide additional samples for statistical reliability.

APPENDIX 10

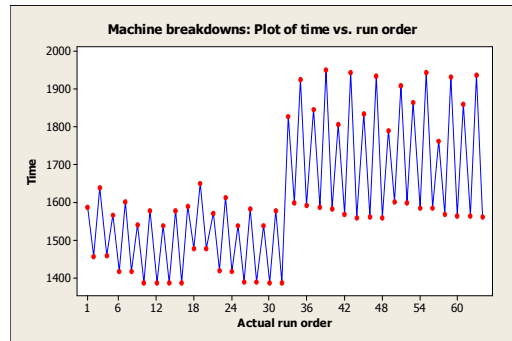
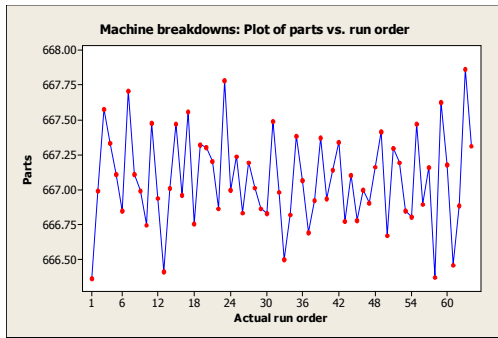
FREQUENT MACHINE BREAKDOWNS SCENARIO: EXPLORATORY DATA ANALYSIS

The histogram and probability plot for the response number of completed parts confirm that the data is normally distributed for such response ($P\text{-value} > 0.05$) whereas, for the responses cost and time the data is obviously far from resembling a normal distribution.

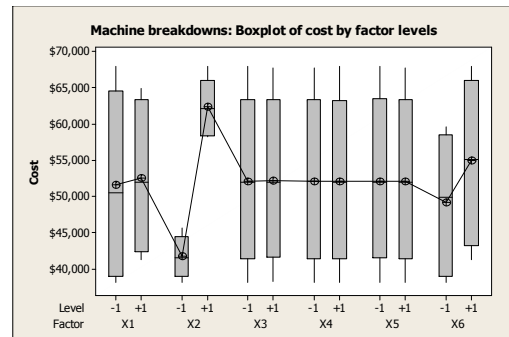
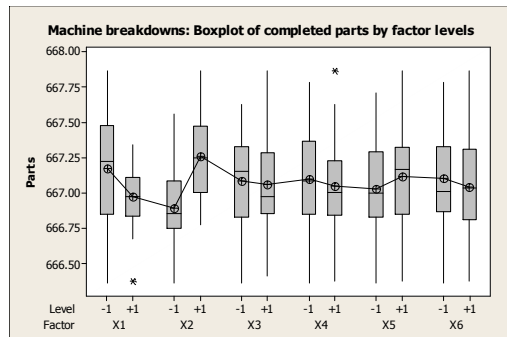


Time series plots do not show any relationship between the sequence of the experiments and the level of the three responses.

APPENDIX 10 (continued)



Box plots show that factor X2 (buffer capacity) may be a significant factor in terms of both throughput and cost whereas, in terms of time in the system, factors X1 (skill level of operators) and X6 (duration of set ups) may be the most important factors.



Factors

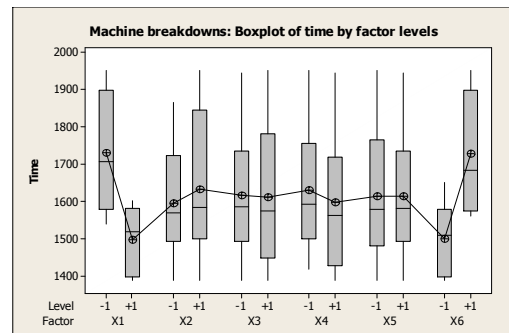
X1: Skill level of operators

X2: Buffer capacity

X3: Number of AVGs

X4: Speed of AVGs

X5: Loading capacity of AVGs



APPENDIX 11

FREQUENT MACHINE BREAKDOWNS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		667.072			
Operators skills	-0.195	-0.097	-6.240	0.608	8.46%
Buffer capacity	0.367	0.184	11.744	2.155	29.97%
Number of vehicles	-0.023	-0.011	-0.736	0.008	0.12%
Vehicle speed	-0.049	-0.025	-1.568	0.038	0.53%
Loading capacity	0.086	0.043	2.752	0.118	1.65%
Set up duration	-0.06	-0.03	-1.920	0.058	0.80%
Operators skills*Buffer capacity	-0.13	-0.065	-4.160	0.270	3.76%
Operators skills*Number of vehicles	0.014	0.007	0.448	0.003	0.04%
Operators skills*Vehicle speed	0.059	0.03	1.888	0.056	0.77%
Operators skills*Loading capacity	-0.173	-0.086	-5.536	0.479	6.66%
Operators skills*Set up duration	0.069	0.035	2.208	0.076	1.06%
Buffer capacity*Number of vehicles	0.062	0.031	1.984	0.062	0.86%
Buffer capacity*Vehicle speed	-0.031	-0.016	-0.992	0.015	0.21%
Buffer capacity*Loading capacity	0.017	0.008	0.544	0.005	0.06%
Buffer capacity*Set up duration	-0.01	-0.005	-0.320	0.002	0.02%
Number of vehicles*Vehicle speed	-0.024	-0.012	-0.768	0.009	0.13%
Number of vehicles*Loading capacity	-0.013	-0.007	-0.416	0.003	0.04%
Number of vehicles*Set up duration	-0.023	-0.012	-0.736	0.008	0.12%
Vehicle speed*Loading capacity	-0.017	-0.009	-0.544	0.005	0.06%
Vehicle speed*Set up duration	0.098	0.049	3.136	0.154	2.14%
Loading capacity*Set up duration	0.011	0.006	0.352	0.002	0.03%
Operators skills*Buffer capacity*Number of vehicles	-0.15	-0.075	-4.800	0.360	5.01%
Operators skills*Buffer capacity*Vehicle speed	-0.001	0	-0.032	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	0.103	0.052	3.296	0.170	2.36%
Operators skills*Buffer capacity*Set up duration	0.026	0.013	0.832	0.011	0.15%
Operators skills*Number of vehicles*Vehicle speed	0.109	0.054	3.488	0.190	2.64%
Operators skills*Number of vehicles*Loading capacity	0.053	0.027	1.696	0.045	0.63%
Operators skills*Number of vehicles*Set up duration	0.053	0.027	1.696	0.045	0.63%
Operators skills*Vehicle speed*Loading capacity	-0.002	-0.001	-0.064	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.022	0.011	0.704	0.008	0.11%
Operators skills*Loading capacity*Set up duration	-0.054	-0.027	-1.728	0.047	0.65%
Buffer capacity*Number of vehicles*Vehicle speed	0.089	0.045	2.848	0.127	1.76%
Buffer capacity*Number of vehicles*Loading capacity	0.056	0.028	1.792	0.050	0.70%
Buffer capacity*Number of vehicles*Set up duration	0.021	0.011	0.672	0.007	0.10%
Buffer capacity*Vehicle speed*Loading capacity	0.147	0.074	4.704	0.346	4.81%
Buffer capacity*Vehicle speed*Set up duration	0.021	0.01	0.672	0.007	0.10%
Buffer capacity*Loading capacity*Set up duration	0.153	0.077	4.896	0.375	5.21%
Number of vehicles*Vehicle speed*Loading capacity	0.069	0.034	2.208	0.076	1.06%
Number of vehicles*Vehicle speed*Set up duration	0.03	0.015	0.960	0.014	0.20%
Number of vehicles*Loading capacity*Set up duration	0.013	0.006	0.416	0.003	0.04%
Vehicle speed*Loading capacity*Set up duration	0.002	0.001	0.064	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	-0.032	-0.016	-1.024	0.016	0.23%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.125	-0.063	-4.000	0.250	3.48%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.012	-0.006	-0.384	0.002	0.03%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.082	-0.041	-2.624	0.108	1.50%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	0.047	0.024	1.504	0.035	0.49%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.065	-0.033	-2.080	0.068	0.94%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.032	-0.016	-1.024	0.016	0.23%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.045	-0.022	-1.440	0.032	0.45%
Operators skills*Number of vehicles*Loading capacity*Set up duration	0.046	0.023	1.472	0.034	0.47%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.067	-0.034	-2.144	0.072	1.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.058	-0.029	-1.856	0.054	0.75%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.01	0.005	0.320	0.002	0.02%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.031	-0.016	-0.992	0.015	0.21%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.109	0.055	3.488	0.190	2.64%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.019	0.01	0.608	0.006	0.08%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.057	0.029	1.824	0.052	0.72%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.019	0.01	0.608	0.006	0.08%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.022	-0.011	-0.704	0.008	0.11%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.058	-0.029	-1.856	0.054	0.75%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.077	0.039	2.464	0.095	1.32%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.01	-0.005	-0.320	0.002	0.02%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.061	-0.031	-1.952	0.060	0.83%
TOTAL				7.190	100%

APPENDIX 12

FREQUENT MACHINE BREAKDOWNS SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	666	666.897	-0.54	f	667	667.051	-0.55
a	667	666.725	0.26	af	667	666.879	-0.05
b	668	667.269	0.31	bf	667	667.115	0.27
ab	667	667.397	-0.07	abf	667	667.243	-0.18
c	667	666.747	0.36	cf	667	666.901	-0.21
ac	667	666.875	-0.03	acf	667	667.029	-0.11
bc	668	667.419	0.29	bcf	667	667.265	0.11
abc	667	667.247	-0.13	abcf	667	667.093	-0.16
d	667	666.897	0.09	df	667	667.051	0.09
ad	667	666.725	0.02	adf	667	666.879	0.46
bd	667	667.269	0.21	bdf	667	667.115	-0.34
abd	667	667.225	-0.28	abdf	667	667.243	-0.14
cd	666	666.747	-0.33	cdf	667	666.901	-0.12
acd	667	666.875	0.13	acdf	667	667.029	-0.03
bcd	667	667.419	0.05	bcdf	667	667.265	-0.36
abcd	667	667.247	-0.29	abcdf	667	667.093	0.07
e	668	667.223	0.33	ef	667	667.069	0.34
ae	667	666.707	0.05	aef	667	666.553	0.12
be	667	667.287	0.03	bef	667	667.441	-0.14
abe	667	667.071	0.23	abef	667	667.225	-0.03
ce	667	667.073	0.13	cef	667	666.919	-0.07
ace	667	666.857	0.01	acef	667	666.703	0.10
bce	668	667.437	0.34	bcef	667	667.591	-0.12
abce	667	666.921	0.08	abcef	667	667.075	-0.18
de	667	667.223	0.02	def	667	667.069	0.09
ade	667	666.707	0.13	adef	666	666.553	-0.18
bde	667	667.287	-0.09	bdef	668	667.441	0.18
abde	667	667.071	-0.06	abdef	667	667.225	-0.05
cde	667	667.073	-0.21	cdef	666	666.919	-0.45
acde	667	666.857	-0.03	acdef	667	666.703	0.18
bcde	667	667.437	0.05	bcdef	668	667.591	0.27
abcde	667	666.921	0.06	abcdef	667	667.075	0.24

APPENDIX 13

FREQUENT MACHINE BREAKDOWNS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE TOTAL COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.70695			
Operators skills	0.01276	0.00638	0.408	0.003	0.49%
Buffer capacity	0.17453	0.08727	5.585	0.487	91.27%
Number of vehicles	0.001	0.0005	0.032	0.000	0.00%
Vehicle speed	-0.00037	-0.00019	-0.012	0.000	0.00%
Loading capacity	-0.00044	-0.00022	-0.014	0.000	0.00%
Set up duration	0.04717	0.02359	1.509	0.036	6.67%
Operators skills*Buffer capacity	-0.02075	-0.01037	-0.664	0.007	1.29%
Operators skills*Number of vehicles	-0.00117	-0.00058	-0.037	0.000	0.00%
Operators skills*Vehicle speed	-0.00069	-0.00034	-0.022	0.000	0.00%
Operators skills*Loading capacity	0.00028	0.00014	0.009	0.000	0.00%
Operators skills*Set up duration	-0.00489	-0.00245	-0.156	0.000	0.07%
Buffer capacity*Number of vehicles	-0.00154	-0.00077	-0.049	0.000	0.01%
Buffer capacity*Vehicle speed	-0.00081	-0.00041	-0.026	0.000	0.00%
Buffer capacity*Loading capacity	0.00014	0.00007	0.004	0.000	0.00%
Buffer capacity*Set up duration	0.00493	0.00246	0.158	0.000	0.07%
Number of vehicles*Vehicle speed	-0.00015	-0.00007	-0.005	0.000	0.00%
Number of vehicles*Loading capacity	0.00048	0.00024	0.015	0.000	0.00%
Number of vehicles*Set up duration	0.00254	0.00127	0.081	0.000	0.02%
Vehicle speed*Loading capacity	0.00005	0.00002	0.002	0.000	0.00%
Vehicle speed*Set up duration	0.00259	0.00129	0.083	0.000	0.02%
Loading capacity*Set up duration	-0.00061	-0.0003	-0.020	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles	0.00053	0.00026	0.017	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00052	-0.00026	-0.017	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	0.00002	0.00001	0.001	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00426	-0.00213	-0.136	0.000	0.05%
Operators skills*Number of vehicles*Vehicle speed	0.00044	0.00022	0.014	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	-0.00052	-0.00026	-0.017	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00064	-0.00032	-0.020	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	-0.00008	-0.00004	-0.003	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00012	-0.00006	-0.004	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00027	0.00014	0.009	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	0.00044	0.00022	0.014	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	-0.00034	-0.00017	-0.011	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00002	-0.00001	-0.001	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00006	-0.00003	-0.002	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00009	0.00045	0.029	0.000	0.00%
Buffer capacity*Loading capacity*Set up duration	-0.00003	-0.00001	-0.001	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	-0.00014	-0.00007	-0.004	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00172	-0.00086	-0.055	0.000	0.01%
Number of vehicles*Loading capacity*Set up duration	0.00067	0.00034	0.021	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	0.00039	0.0002	0.012	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00045	0.00023	0.014	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00016	0.00008	0.005	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.00028	0.00014	0.009	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00002	0.00001	0.001	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00045	-0.00023	-0.014	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00001	0.00005	0.003	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00001	0.00005	0.003	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00003	-0.00001	-0.001	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00033	-0.00017	-0.011	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00016	-0.00008	-0.005	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00008	0.00004	0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00069	-0.00034	-0.022	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00027	-0.00013	-0.009	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00006	0.00003	0.002	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00023	-0.00012	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00005	-0.00002	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00004	0.00002	0.013	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00002	0.00001	0.006	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0	0	0.000	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00003	0.00002	0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00015	0.00007	0.005	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00018	-0.00009	-0.006	0.000	0.00%
TOTAL				0.534	100%

APPENDIX 14

ANOVA TABLE FOR THE RESPONSE COST; MACHINE BREAKDOENS SCENARIO

Source	DF	SS	MS	F	P
Operators skills	1	0.002607	0.002607	1397.28	0.000*
Buffer capacity	1	0.487377	0.487377	261253.72	0.000*
Number of vehicles	1	0.000016	0.000016	8.52	0.005*
Vehicle speed	1	0.000002	0.000002	1.18	0.282
Set up duration	1	0.035603	0.035603	19084.53	0.000*
Operators skills*Buffer capacity	1	0.006888	0.006888	3692.30	0.000*
Operators skills*Number of vehicles	1	0.000022	0.000022	11.69	0.001*
Operators skills*Set up duration	1	0.000383	0.000383	205.40	0.000*
Buffer capacity*Number of vehicles	1	0.000038	0.000038	20.25	0.000*
Buffer capacity*Vehicle speed	1	0.000011	0.000011	5.66	0.022
Buffer capacity*Set up duration	1	0.000389	0.000389	208.40	0.000*
Number of vehicles*Vehicle speed	1	0.000000	0.000000	0.19	0.669
Number of vehicles*Set up duration	1	0.000103	0.000103	55.25	0.000*
Vehicle speed*Set up duration	1	0.000107	0.000107	57.50	0.000*
Operators skills*Buffer capacity* Set up duration	1	0.000290	0.000290	155.68	0.000*
Buffer capacity*Vehicle speed* Set up duration	1	0.000013	0.000013	6.93	0.011
Number of vehicles*Vehicle speed* Set up duration	1	0.000048	0.000048	25.52	0.000*
Error	46	0.000086	0.000002		
Total	63	0.533982			

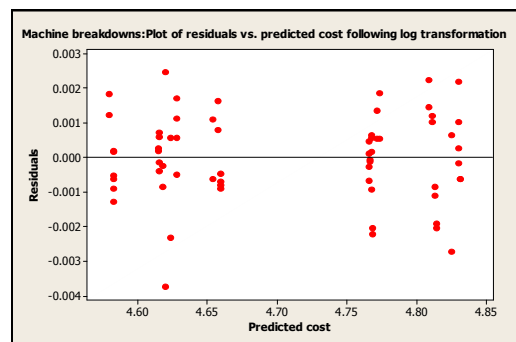
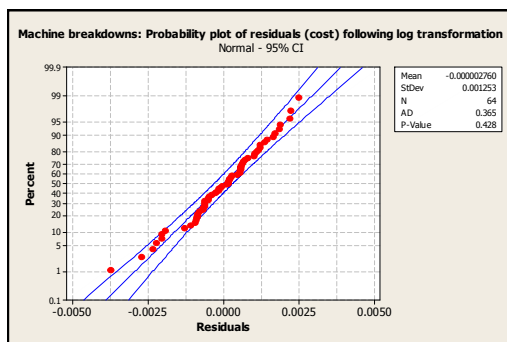
S = 0.00136584 R-Sq = 99.98% R-Sq(adj) = 99.98%

* Significant effects

APPENDIX 15

FREQUENT MACHINE BREAKDOWNS SCENARIO: RESIDUALS FOR THE RESPONSE TOTAL COST FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	4.581312	4.5826	-0.0013	f	4.622034	4.61956	0.0025
a	4.617036	4.6179	-0.0009	af	4.654678	4.65358	0.0011
b	4.771667	4.77114	0.0005	bf	4.825294	4.82466	0.0006
ab	4.774016	4.77348	0.0005	abf	4.81091	4.80868	0.0022
c	4.582201	4.58204	0.0002	cf	4.627013	4.62752	-0.0005
ac	4.615737	4.61502	0.0007	acf	4.658426	4.65922	-0.0008
bc	4.76657	4.7675	-0.0009	bcf	4.830557	4.82954	0.0010
abc	4.768162	4.76752	0.0006	abcf	4.812433	4.81124	0.0012
d	4.581036	4.5792	0.0018	df	4.623532	4.62296	0.0006
ad	4.614685	4.6145	0.0002	adf	4.658612	4.65698	0.0016
bd	4.765825	4.76594	-0.0001	bdf	4.832047	4.82986	0.0022
abd	4.766055	4.76828	-0.0022	abdf	4.811833	4.81388	-0.0020
cd	4.581561	4.58208	-0.0005	cdf	4.628046	4.62748	0.0006
acd	4.614906	4.61506	-0.0002	acdf	4.658704	4.65918	-0.0005
bcd	4.765465	4.76574	-0.0003	bcdf	4.830663	4.8313	-0.0006
abcd	4.766211	4.76576	0.0005	abcdf	4.812139	4.813	-0.0009
e	4.581704	4.5826	-0.0009	ef	4.615827	4.61956	-0.0037
ae	4.617647	4.6179	-0.0003	aef	4.652963	4.65358	-0.0006
be	4.772481	4.77114	0.0013	bef	4.82193	4.82466	-0.0027
abe	4.775348	4.77348	0.0019	abef	4.810129	4.80868	0.0014
ce	4.582229	4.58204	0.0002	cef	4.628654	4.62752	0.0011
ace	4.615616	4.61502	0.0006	acef	4.658305	4.65922	-0.0009
bce	4.767659	4.7675	0.0002	bcef	4.82938	4.82954	-0.0002
abce	4.768083	4.76752	0.0006	abcef	4.812254	4.81124	0.0010
de	4.580416	4.5792	0.0012	def	4.620624	4.62296	-0.0023
ade	4.614767	4.6145	0.0003	adef	4.657768	4.65698	0.0008
bde	4.765883	4.76594	-0.0001	bdef	4.830118	4.82986	0.0003
abde	4.766236	4.76828	-0.0020	abdef	4.811951	4.81388	-0.0019
cde	4.581443	4.58208	-0.0006	cdef	4.629175	4.62748	0.0017
acde	4.614674	4.61506	-0.0004	acdef	4.658486	4.65918	-0.0007
bcde	4.76507	4.76574	-0.0007	bcdef	4.830673	4.8313	-0.0006
abcde	4.765863	4.76576	0.0001	abcdef	4.811901	4.813	-0.0011



APPENDIX 16

FREQUENT MACHINE BREAKDOWNS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.20527			
Operators skills	-0.06189	-0.03095	-1.980	0.061	46.96%
Buffer capacity	0.00915	0.00457	0.293	0.001	1.03%
Number of vehicles	-0.00151	-0.00075	-0.048	0.000	0.03%
Vehicle speed	-0.00949	-0.00475	-0.304	0.001	1.10%
Loading capacity	0.00039	0.0002	0.012	0.000	0.00%
Set up duration	0.06113	0.03057	1.956	0.060	45.81%
Operators skills*Buffer capacity	-0.00967	-0.00483	-0.309	0.001	1.15%
Operators skills*Number of vehicles	-0.00354	-0.00177	-0.113	0.000	0.15%
Operators skills*Vehicle speed	-0.00283	-0.00142	-0.091	0.000	0.10%
Operators skills*Loading capacity	0.00086	0.00043	0.028	0.000	0.01%
Operators skills*Set up duration	-0.01381	-0.0069	-0.442	0.003	2.34%
Buffer capacity*Number of vehicles	-0.00149	-0.00075	-0.048	0.000	0.03%
Buffer capacity*Vehicle speed	0.00031	0.00016	0.010	0.000	0.00%
Buffer capacity*Loading capacity	0.00023	0.00011	0.007	0.000	0.00%
Buffer capacity*Set up duration	0.00314	0.00157	0.100	0.000	0.12%
Number of vehicles*Vehicle speed	0.00284	0.00142	0.091	0.000	0.10%
Number of vehicles*Loading capacity	0.00065	0.00033	0.021	0.000	0.01%
Number of vehicles*Set up duration	0.00444	0.00222	0.142	0.000	0.24%
Vehicle speed*Loading capacity	-0.00056	-0.00028	-0.018	0.000	0.00%
Vehicle speed*Set up duration	0.00489	0.00244	0.156	0.000	0.29%
Loading capacity*Set up duration	-0.00106	-0.00053	-0.034	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles	0.0017	0.00085	0.054	0.000	0.04%
Operators skills*Buffer capacity*Vehicle speed	-0.00052	-0.00026	-0.017	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.00022	-0.00011	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00364	-0.00182	-0.116	0.000	0.16%
Operators skills*Number of vehicles*Vehicle speed	0.00144	0.00072	0.046	0.000	0.03%
Operators skills*Number of vehicles*Loading capacity	-0.00152	-0.00076	-0.049	0.000	0.03%
Operators skills*Number of vehicles*Set up duration	-0.0017	-0.00085	-0.054	0.000	0.04%
Operators skills*Vehicle speed*Loading capacity	-0.00016	-0.00008	-0.005	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00035	-0.00018	-0.011	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00045	0.00023	0.014	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00033	-0.00016	-0.011	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00084	-0.00042	-0.027	0.000	0.01%
Buffer capacity*Number of vehicles*Set up duration	-0.00072	-0.00036	-0.023	0.000	0.01%
Buffer capacity*Vehicle speed*Loading capacity	0.00009	0.00004	0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00089	0.00045	0.028	0.000	0.01%
Buffer capacity*Loading capacity*Set up duration	-0.00001	-0.00001	0.000	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00038	0.00019	0.012	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00256	-0.00128	-0.082	0.000	0.08%
Number of vehicles*Loading capacity*Set up duration	0.00137	0.00068	0.044	0.000	0.02%
Vehicle speed*Loading capacity*Set up duration	0.0006	0.0003	0.019	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00058	0.00029	0.019	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00082	0.00041	0.026	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.00105	0.00052	0.034	0.000	0.01%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.00009	-0.00005	-0.003	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00084	-0.00042	-0.027	0.000	0.01%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00021	0.00011	0.007	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.0003	0.00015	0.010	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00041	-0.0002	-0.013	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00087	-0.00043	-0.028	0.000	0.01%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00007	-0.00004	-0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00012	-0.00006	-0.004	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00095	-0.00048	-0.030	0.000	0.01%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00074	-0.00037	-0.024	0.000	0.01%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00012	0.00006	0.004	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00006	-0.00003	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00001	0.00001	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00099	0.0005	0.032	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00064	0.00032	0.020	0.000	0.01%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00023	-0.00011	-0.007	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00035	-0.00018	-0.011	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00005	-0.00002	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00009	0.00004	0.003	0.000	0.00%
TOTAL				0.131	100%

APPENDIX 17

ANOVA TABLE FOR THE RESPONSE TIME; MACHINE BREAKDOWNS SCENARIO

Source	DF	SS	MS	F	P
Operators skills	1	0.0612929	0.0612929	8727.27	0.000*
Buffer capacity	1	0.0013389	0.0013389	190.64	0.000*
Number of vehicles	1	0.0000364	0.0000364	5.18	0.028
Vehicle speed	1	0.0014422	0.0014422	205.34	0.000*
Set up duration	1	0.0597981	0.0597981	8514.42	0.000*
Operators skills*Buffer capacity	1	0.0014947	0.0014947	212.82	0.000*
Operators skills*Number of vehicles	1	0.0002010	0.0002010	28.61	0.000*
Operators skills*Vehicle speed	1	0.0001284	0.0001284	18.28	0.000*
Operators skills*Set up duration	1	0.0030511	0.0030511	434.43	0.000*
Buffer capacity*Number of vehicles	1	0.0000356	0.0000356	5.07	0.029
Buffer capacity*Vehicle speed	1	0.0000016	0.0000016	0.22	0.640
Buffer capacity*Set up duration	1	0.0001578	0.0001578	22.48	0.000*
Number of vehicles*Vehicle speed	1	0.0001291	0.0001291	18.38	0.000*
Number of vehicles*Set up duration	1	0.0003161	0.0003161	45.01	0.000*
Vehicle speed*Set up duration	1	0.0003820	0.0003820	54.39	0.000*
Operators skills*Buffer capacity* Number of vehicles	1	0.0000464	0.0000464	6.61	0.014
Operators skills*Buffer capacity* Set up duration	1	0.0002124	0.0002124	30.24	0.000*
Operators skills*Number of vehicles*1 Set up duration	1	0.0000465	0.0000465	6.61	0.014
Number of vehicles*Vehicle speed* Set up duration	1	0.0001051	0.0001051	14.97	0.000*
Error	44	0.0003090	0.0000070		
Total	63	0.1305251			

S = 0.00265012 R-Sq = 99.76% R-Sq(adj) = 99.66%

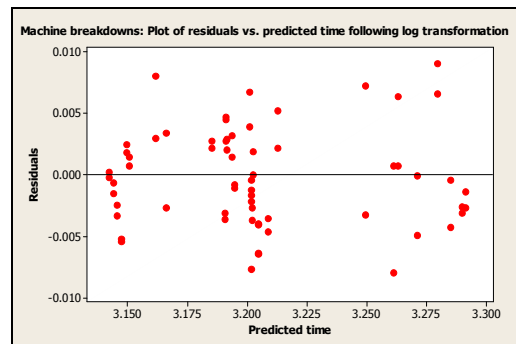
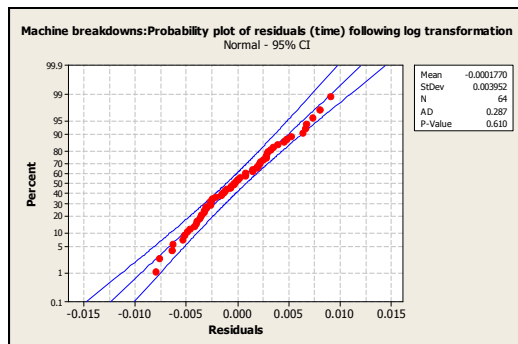
* Significant effects

APPENDIX 18

FREQUENT MACHINE BREAKDOWNS SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}
(1)	3.200409	3.20166	-0.0013
a	3.163287	3.16596	-0.0027
b	3.21468	3.21254	0.0021
ab	3.164369	3.1614	0.0030
c	3.194776	3.19332	0.0015
ac	3.151258	3.15054	0.0007
bc	3.204676	3.2008	0.0039
abc	3.151221	3.14938	0.0018
d	3.18758	3.18486	0.0027
ad	3.142242	3.14378	-0.0015
bd	3.198325	3.20202	-0.0037
abd	3.141889	3.1452	-0.0033
cd	3.187407	3.19052	-0.0031
acd	3.141812	3.14206	-0.0002
bcd	3.197931	3.20428	-0.0063
abcd	3.141792	3.14718	-0.0054
e	3.201261	3.20166	-0.0004
ae	3.169372	3.16596	0.0034
be	3.217777	3.21254	0.0052
abe	3.169428	3.1614	0.0080
ce	3.196488	3.19332	0.0032
ace	3.151965	3.15054	0.0014
bce	3.207517	3.2008	0.0067
abce	3.151831	3.14938	0.0025
de	3.187047	3.18486	0.0022
ade	3.143135	3.14378	-0.0006
bde	3.199344	3.20202	-0.0027
abde	3.142748	3.1452	-0.0025
cde	3.186892	3.19052	-0.0036
acde	3.14229	3.14206	0.0002
bcde	3.19784	3.20428	-0.0064
abcde	3.141961	3.14718	-0.0052

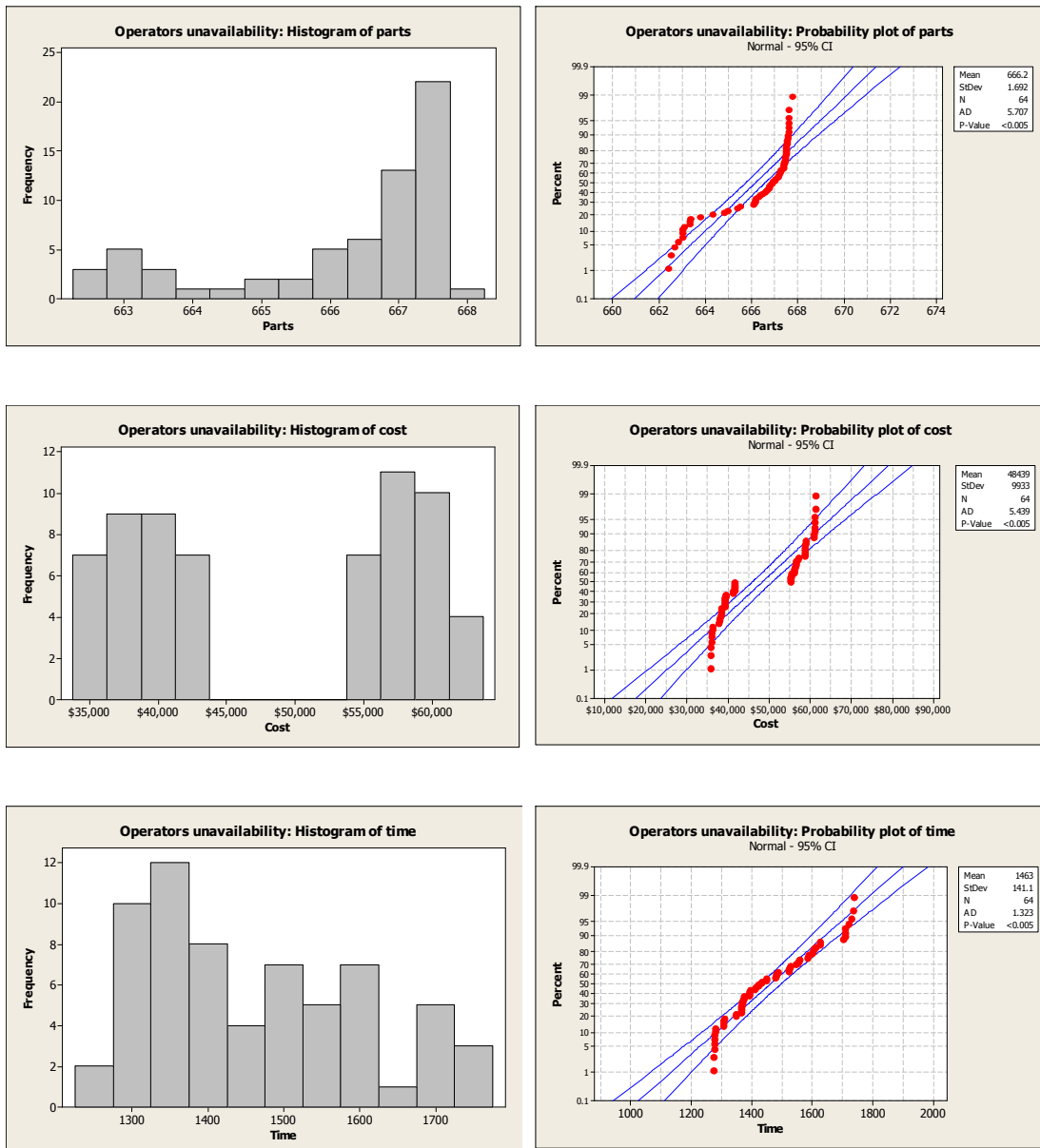
Run	y	\hat{y}	e=y- \hat{y}
f	3.261719	3.26098	0.0007
af	3.203697	3.20836	-0.0047
bf	3.284412	3.28482	-0.0004
abf	3.202221	3.2022	0.0000
cf	3.265988	3.27092	-0.0049
acf	3.200421	3.20442	-0.0040
bcf	3.289986	3.29136	-0.0014
abcf	3.199526	3.20166	-0.0021
df	3.256553	3.2493	0.0073
adf	3.195468	3.191	0.0045
bdf	3.28847	3.27942	0.0091
abdf	3.193166	3.19112	0.0020
cdf	3.263702	3.263	0.0007
acdf	3.193534	3.19082	0.0027
bcdf	3.286597	3.28972	-0.0031
abcdf	3.193284	3.19434	-0.0011
ef	3.252991	3.26098	-0.0080
aef	3.204804	3.20836	-0.0036
bef	3.280589	3.28482	-0.0042
abef	3.204069	3.2022	0.0019
cef	3.270833	3.27092	-0.0001
acef	3.200344	3.20442	-0.0041
bcef	3.288686	3.29136	-0.0027
abcef	3.199999	3.20166	-0.0017
def	3.24601	3.2493	-0.0033
adef	3.195722	3.191	0.0047
bdef	3.286036	3.27942	0.0066
abdef	3.193995	3.19112	0.0029
cdef	3.269336	3.263	0.0063
acdef	3.193992	3.20166	-0.0077
bcdef	3.287134	3.28972	-0.0026
abcdef	3.193559	3.19434	-0.0008



APPENDIX 19

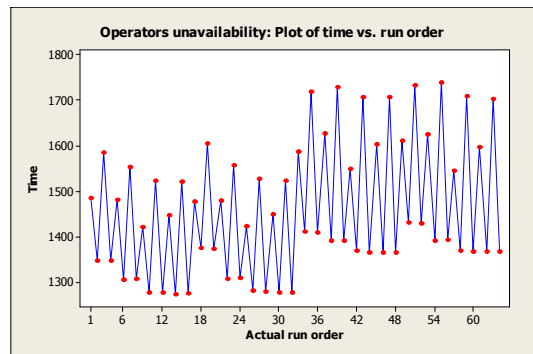
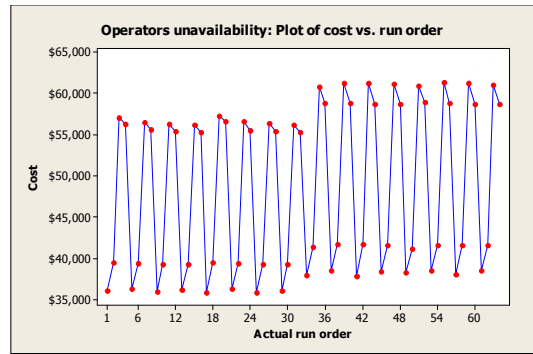
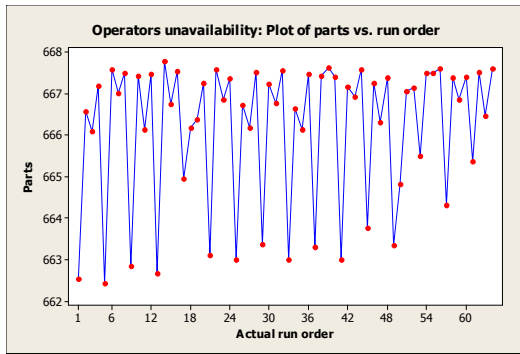
FREQUENT OPERATOR UNAVAILABILITY SCENARIO: EXPLORATORY DATA ANALYSIS

The histograms and probability plots show that none of the three responses display a normally distributed behaviour; in consequence, data transformation may be required for the three responses in this scenario.

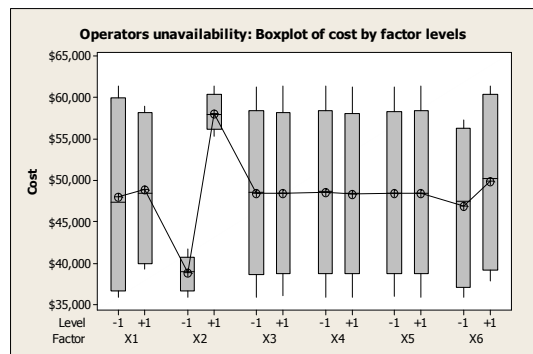
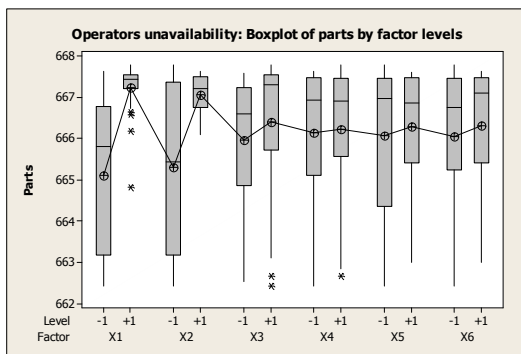


Time series plots do not show any relationship between the sequence of the experiments and the level of the three responses.

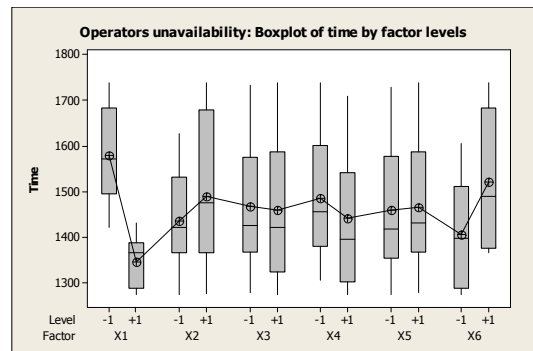
APPENDIX 19 (continued)



The box plots show that factors X1 (skill level of operators) and X2 (buffer capacity) may be a significant factor in terms of throughput. Moreover, factor X2 may be a very important factor in terms of total cost. And, in terms of time in the system, factors X1 (skill level of operators) and X6 (duration of set ups) may be the most important factors.



- Factors**
- X1:** Skill level of operators
 - X2:** Buffer capacity
 - X3:** Number of AVGs
 - X4:** Speed of AVGs
 - X5:** Loading capacity of AVGs



APPENDIX 20

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		666.173			
Operators skills	2.132	1.066	68.224	72.727	40.31%
Buffer capacity	1.773	0.887	56.736	50.296	27.88%
Number of vehicles	0.436	0.218	13.952	3.042	1.69%
Vehicle speed	0.1	0.05	3.200	0.160	0.09%
Loading capacity	0.233	0.117	7.456	0.869	0.48%
Set up duration	0.26	0.13	8.320	1.082	0.60%
Operators skills*Buffer capacity	-1.387	-0.694	-44.384	30.780	17.06%
Operators skills*Number of vehicles	0.057	0.029	1.824	0.052	0.03%
Operators skills*Vehicle speed	0.231	0.115	7.392	0.854	0.47%
Operators skills*Loading capacity	-0.423	-0.211	-13.536	2.863	1.59%
Operators skills*Set up duration	-0.332	-0.166	-10.624	1.764	0.98%
Buffer capacity*Number of vehicles	-0.158	-0.079	-5.056	0.399	0.22%
Buffer capacity*Vehicle speed	-0.17	-0.085	-5.440	0.462	0.26%
Buffer capacity*Loading capacity	-0.174	-0.087	-5.568	0.484	0.27%
Buffer capacity*Set up duration	-0.076	-0.038	-2.432	0.092	0.05%
Number of vehicles*Vehicle speed	-0.225	-0.112	-7.200	0.810	0.45%
Number of vehicles*Loading capacity	0.09	0.045	2.880	0.130	0.07%
Number of vehicles*Set up duration	0.145	0.072	4.640	0.336	0.19%
Vehicle speed*Loading capacity	-0.03	-0.015	-0.960	0.014	0.01%
Vehicle speed*Set up duration	0.076	0.038	2.432	0.092	0.05%
Loading capacity*Set up duration	0.076	0.038	2.432	0.092	0.05%
Operators skills*Buffer capacity*Number of vehicles	-0.219	-0.11	-7.008	0.767	0.43%
Operators skills*Buffer capacity*Vehicle speed	-0.022	-0.011	-0.704	0.008	0.00%
Operators skills*Buffer capacity*Loading capacity	0.349	0.174	11.168	1.949	1.08%
Operators skills*Buffer capacity*Set up duration	0.175	0.088	5.600	0.490	0.27%
Operators skills*Number of vehicles*Vehicle speed	-0.122	-0.061	-3.904	0.238	0.13%
Operators skills*Number of vehicles*Loading capacity	0.111	0.056	3.552	0.197	0.11%
Operators skills*Number of vehicles*Set up duration	-0.129	-0.065	-4.128	0.266	0.15%
Operators skills*Vehicle speed*Loading capacity	0.136	0.068	4.352	0.296	0.16%
Operators skills*Vehicle speed*Set up duration	0	0	0.000	0.000	0.00%
Operators skills*Loading capacity*Set up duration	-0.057	-0.028	-1.824	0.052	0.03%
Buffer capacity*Number of vehicles*Vehicle speed	-0.016	-0.008	-0.512	0.004	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.126	-0.063	-4.032	0.254	0.14%
Buffer capacity*Number of vehicles*Set up duration	-0.262	-0.131	-8.384	1.098	0.61%
Buffer capacity*Vehicle speed*Loading capacity	0.001	0.001	0.032	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	-0.182	-0.091	-5.824	0.530	0.29%
Buffer capacity*Loading capacity*Set up duration	-0.04	-0.02	-1.280	0.026	0.01%
Number of vehicles*Vehicle speed*Loading capacity	0.009	0.004	0.288	0.001	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.229	-0.115	-7.328	0.839	0.47%
Number of vehicles*Loading capacity*Set up duration	0.172	0.086	5.504	0.473	0.26%
Vehicle speed*Loading capacity*Set up duration	0.16	0.08	5.120	0.410	0.23%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.275	0.137	8.800	1.210	0.67%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.016	0.008	0.512	0.004	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.226	0.113	7.232	0.817	0.45%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.068	-0.034	-2.176	0.074	0.04%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	0.049	0.024	1.568	0.038	0.02%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.008	0.004	0.256	0.001	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.135	-0.068	-4.320	0.292	0.16%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.117	0.058	3.744	0.219	0.12%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.018	-0.009	-0.576	0.005	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.036	0.018	1.152	0.021	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.095	0.048	3.040	0.144	0.08%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.05	0.025	1.600	0.040	0.02%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.122	-0.061	-3.904	0.238	0.13%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.198	-0.099	-6.336	0.627	0.35%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.152	-0.076	-4.864	0.370	0.20%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.038	0.019	1.216	0.023	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.047	0.024	1.504	0.035	0.02%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.11	0.055	3.520	0.194	0.11%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.007	0.004	0.224	0.001	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.034	0.017	1.088	0.018	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.186	0.093	5.952	0.554	0.31%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.104	-0.052	-3.328	0.173	0.10%
TOTAL				180.399	100%

APPENDIX 21

**ANOVA TABLE FOR THE RESPONSE NUMBER OF PARTS; OPERATOR
UNAVAILABILITY SCENARIO**

Source	DF	SS	MS	F	P
Operator skills	1	72.740	72.740	209.35	0.000*
Buffer capacity	1	50.297	50.297	144.76	0.000*
Number of vehicles	1	3.038	3.038	8.74	0.005*
Loading capacity	1	0.869	0.869	2.50	0.119
Operator skills*Buffer capacity	1	30.792	30.792	88.62	0.000*
Operator skills>Loading capacity	1	2.858	2.858	8.22	0.006*
Error	57	19.805	0.347		
Total	63	180.398			

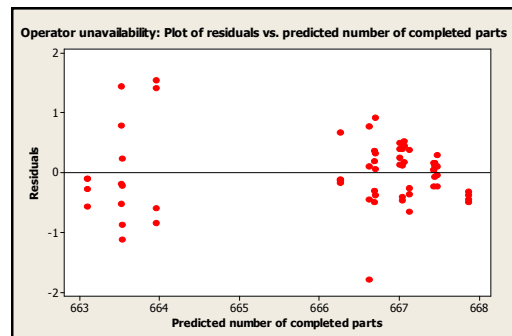
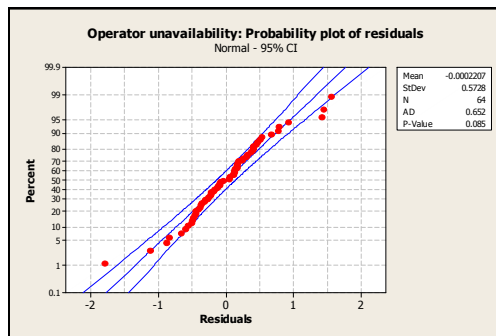
S = 0.589452 R-Sq = 89.02% R-Sq(adj) = 87.87%

* Significant factors

APPENDIX 22

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	663	663.097	-0.57	f	663	663.097	-0.10
a	667	667.039	-0.47	af	667	667.039	-0.41
b	666	666.259	-0.17	bf	666	666.259	-0.12
ab	667	667.425	-0.24	abf	667	667.425	0.05
c	662	663.533	-1.12	cf	663	663.533	-0.22
ac	668	667.475	0.11	acf	667	667.475	-0.04
bc	667	666.695	0.31	bcf	668	666.695	0.92
abc	667	667.861	-0.37	abcf	667	667.861	-0.45
d	663	663.097	-0.27	df	663	663.097	-0.10
ad	667	667.039	0.39	adf	667	667.039	0.12
bd	666	666.259	-0.13	bdf	667	666.259	0.67
abd	667	667.425	0.04	abdf	668	667.425	0.16
cd	663	663.533	-0.88	cdf	664	663.533	0.23
acd	668	667.475	0.30	acdf	667	667.475	-0.23
bcd	667	666.695	0.06	bcdf	666	666.695	-0.38
abcd	668	667.861	-0.33	abcdf	667	667.861	-0.49
e	665	663.519	1.44	ef	663	663.519	-0.19
ae	666	666.617	-0.45	aef	665	666.617	-1.80
be	666	666.681	-0.31	bef	667	666.681	0.36
abe	667	667.003	0.24	abef	667	667.003	0.14
ce	663	663.955	-0.84	cef	666	663.955	1.55
ace	668	667.053	0.53	acef	667	667.053	0.44
bce	667	667.117	-0.26	bcef	667	667.117	0.38
abce	667	667.439	-0.08	abcef	668	667.439	0.16
de	663	663.519	-0.52	def	664	663.519	0.78
ade	667	666.617	0.10	adef	667	666.617	0.77
bde	666	666.681	-0.50	bdef	667	666.681	0.19
abde	668	667.003	0.50	abdef	667	667.003	0.39
cde	663	663.955	-0.60	cdef	665	663.955	1.42
acde	667	667.053	0.18	acdef	668	667.053	0.46
bcde	667	667.117	-0.36	bcdef	666	667.117	-0.66
abcde	668	667.439	0.12	abcdef	668	667.439	0.15



APPENDIX 23

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE TOTAL COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.67599			
Operators skills	0.01253	0.00627	0.401	0.003	0.49%
Buffer capacity	0.17539	0.0877	5.612	0.492	95.33%
Number of vehicles	0.00055	0.00027	0.018	0.000	0.00%
Vehicle speed	-0.00159	-0.00079	-0.051	0.000	0.01%
Loading capacity	0.00021	0.0001	0.007	0.000	0.00%
Set up duration	0.02669	0.01335	0.854	0.011	2.21%
Operators skills*Buffer capacity	-0.02453	-0.01227	-0.785	0.010	1.86%
Operators skills*Number of vehicles	-0.0011	-0.00055	-0.035	0.000	0.00%
Operators skills*Vehicle speed	0.00013	0.00006	0.004	0.000	0.00%
Operators skills*Loading capacity	-0.00018	-0.00009	-0.006	0.000	0.00%
Operators skills*Set up duration	-0.00313	-0.00157	-0.100	0.000	0.03%
Buffer capacity*Number of vehicles	-0.00196	-0.00098	-0.063	0.000	0.01%
Buffer capacity*Vehicle speed	-0.00106	-0.00053	-0.034	0.000	0.00%
Buffer capacity*Loading capacity	0.00022	0.00011	0.007	0.000	0.00%
Buffer capacity*Set up duration	0.00205	0.00103	0.066	0.000	0.01%
Number of vehicles*Vehicle speed	0.00018	0.00009	0.006	0.000	0.00%
Number of vehicles*Loading capacity	-0.00024	-0.00012	-0.008	0.000	0.00%
Number of vehicles*Set up duration	0.00143	0.00072	0.046	0.000	0.01%
Vehicle speed*Loading capacity	-0.00017	-0.00008	-0.005	0.000	0.00%
Vehicle speed*Set up duration	0.00151	0.00075	0.048	0.000	0.01%
Loading capacity*Set up duration	0.00014	0.00007	0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles	0.00056	0.00028	0.018	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00066	-0.00033	-0.021	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	0.00024	0.00012	0.008	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00181	-0.00091	-0.058	0.000	0.01%
Operators skills*Number of vehicles*Vehicle speed	0.0001	0.00005	0.003	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	0.00016	0.00008	0.005	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	0.00005	0.00002	0.002	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	0.00004	0.00002	0.001	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00033	0.00016	0.011	0.000	0.00%
Operators skills*Loading capacity*Set up duration	-0.00044	-0.00022	-0.014	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	0.00053	0.00026	0.017	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00016	-0.00008	-0.005	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00027	0.00014	0.009	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00029	-0.00015	-0.009	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00077	0.00039	0.025	0.000	0.00%
Buffer capacity*Loading capacity*Set up duration	-0.0004	-0.0002	-0.013	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00016	0.00008	0.005	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00106	-0.00053	-0.034	0.000	0.00%
Number of vehicles*Loading capacity*Set up duration	-0.00006	-0.00003	-0.002	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	-0.00001	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00059	0.00029	0.019	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.00008	-0.00004	-0.003	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.00022	-0.00011	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.00001	-0.00001	0.000	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00055	-0.00027	-0.018	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00051	0.00026	0.016	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00011	0.00006	0.004	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00041	-0.0002	-0.013	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	0.00044	0.00022	0.014	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00019	0.0001	0.006	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00008	0.00004	0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00068	-0.00034	-0.022	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.0003	0.00015	0.010	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00001	0	0.000	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00011	-0.00005	-0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00008	0.00004	0.003	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00057	0.00028	0.018	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00035	-0.00017	-0.011	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00011	-0.00005	-0.004	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00016	-0.00008	-0.005	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00023	-0.00011	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00019	0.00009	0.006	0.000	0.00%
TOTAL				0.516	100%

APPENDIX 24

**ANOVA TABLE FOR THE RESPONSE COST; OPERATOR UNAVAILABILITY
SCENARIO**

Source	DF	SS	MS	F	P
Operator skills	1	0.002513	0.002513	390.45	0.000*
Buffer capacity	1	0.492206	0.492206	76469.78	0.000*
Set up duration	1	0.011401	0.011401	1771.32	0.000*
Operator skills*Buffer capacity	1	0.009631	0.009631	1496.23	0.000*
Operator skills*Set up duration	1	0.000157	0.000157	24.41	0.000*
Buffer capacity*Set up duration	1	0.000067	0.000067	10.45	0.002*
Error	57	0.000367	0.000006		
Total	63	0.516343			

S = 0.00253705 R-Sq = 99.93% R-Sq(adj) = 99.92%

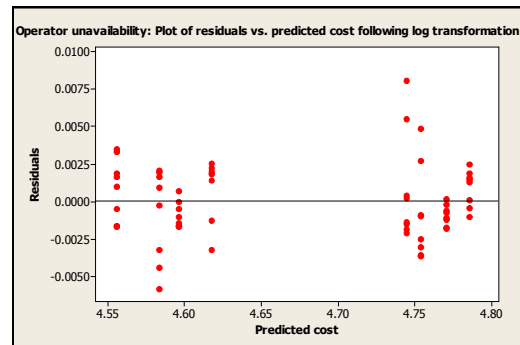
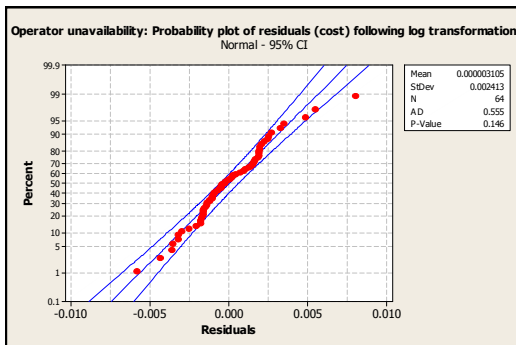
* Significant factors

APPENDIX 25

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: RESIDUALS FOR THE RESPONSE TOTAL COST

Run	y	\hat{y}	e=y- \hat{y}
(1)	4.5569	4.5559	0.0010
a	4.5960	4.5961	0.0000
b	4.7564	4.7537	0.0027
ab	4.7504	4.7449	0.0055
c	4.5594	4.5559	0.0035
ac	4.5956	4.5961	-0.0005
bc	4.7528	4.7537	-0.0010
abc	4.7453	4.7449	0.0004
d	4.5553	4.5559	-0.0005
ad	4.5946	4.5961	-0.0014
bd	4.7507	4.7537	-0.0030
abd	4.7434	4.7449	-0.0015
cd	4.5578	4.5559	0.0019
acd	4.5945	4.5961	-0.0016
bcd	4.7501	4.7537	-0.0037
abcd	4.7428	4.7449	-0.0021
e	4.5541	4.5559	-0.0017
ae	4.5967	4.5961	0.0007
be	4.7586	4.7537	0.0048
abe	4.7529	4.7449	0.0080
ce	4.5591	4.5559	0.0033
ace	4.5950	4.5961	-0.0010
bce	4.7528	4.7537	-0.0009
abce	4.7451	4.7449	0.0002
de	4.5542	4.5559	-0.0016
ade	4.5944	4.5961	-0.0017
bde	4.7512	4.7537	-0.0025
abde	4.7435	4.7449	-0.0014
cde	4.5575	4.5559	0.0016
acde	4.5944	4.5961	-0.0016
bcde	4.7502	4.7537	-0.0036
abcde	4.7430	4.7449	-0.0018

Run	y	\hat{y}	e=y- \hat{y}
f	4.579254	4.58364	-0.0044
af	4.61633	4.61758	-0.0012
bf	4.784578	4.78564	-0.0011
abf	4.769888	4.7705	-0.0006
cf	4.585551	4.58364	0.0019
acf	4.620091	4.61758	0.0025
bcf	4.787494	4.78564	0.0019
abcf	4.769764	4.7705	-0.0007
df	4.577807	4.58364	-0.0058
adf	4.61981	4.61758	0.0022
bdf	4.787115	4.78564	0.0015
abdf	4.769423	4.7705	-0.0011
cdf	4.584564	4.58364	0.0009
acdf	4.619415	4.61758	0.0018
bcdf	4.786899	4.78564	0.0013
abcdf	4.768694	4.7705	-0.0018
ef	4.583382	4.58364	-0.0003
aef	4.614328	4.61758	-0.0033
bef	4.785211	4.78564	-0.0004
abef	4.770648	4.7705	0.0001
cef	4.585708	4.58364	0.0021
acef	4.619469	4.61758	0.0019
bcef	4.788086	4.78564	0.0024
abcef	4.770281	4.7705	-0.0002
def	4.580413	4.58364	-0.0032
adef	4.618951	4.61758	0.0014
bdef	4.787203	4.78564	0.0016
abdef	4.769255	4.7705	-0.0012
cdef	4.585281	4.58364	0.0016
acdef	4.619534	4.61758	0.0020
bcdef	4.785701	4.78564	0.0001
abcdef	4.768758	4.7705	-0.0017



APPENDIX 26

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.1633			
Operators skills	-0.06898	-0.03449	-2.207	0.076	71.04%
Buffer capacity	0.01477	0.00738	0.473	0.003	3.26%
Number of vehicles	-0.00238	-0.00119	-0.076	0.000	0.08%
Vehicle speed	-0.01334	-0.00667	-0.427	0.003	2.66%
Loading capacity	0.00168	0.00084	0.054	0.000	0.04%
Set up duration	0.03399	0.017	1.088	0.018	17.25%
Operators skills*Buffer capacity	-0.01484	-0.00742	-0.475	0.004	3.29%
Operators skills*Number of vehicles	-0.00472	-0.00236	-0.151	0.000	0.33%
Operators skills*Vehicle speed	-0.00226	-0.00113	-0.072	0.000	0.08%
Operators skills*Loading capacity	0.00064	0.00032	0.020	0.000	0.01%
Operators skills*Set up duration	-0.00772	-0.00386	-0.247	0.001	0.89%
Buffer capacity*Number of vehicles	-0.00234	-0.00117	-0.075	0.000	0.08%
Buffer capacity*Vehicle speed	0.00044	0.00022	0.014	0.000	0.00%
Buffer capacity*Loading capacity	0.00039	0.0002	0.012	0.000	0.00%
Buffer capacity*Set up duration	0.00147	0.00074	0.047	0.000	0.03%
Number of vehicles*Vehicle speed	0.00451	0.00225	0.144	0.000	0.30%
Number of vehicles*Loading capacity	-0.00123	-0.00062	-0.039	0.000	0.02%
Number of vehicles*Set up duration	0.00278	0.00139	0.089	0.000	0.12%
Vehicle speed*Loading capacity	-0.00127	-0.00064	-0.041	0.000	0.02%
Vehicle speed*Set up duration	0.00314	0.00157	0.100	0.000	0.15%
Loading capacity*Set up duration	-0.00016	-0.00008	-0.005	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles	0.00265	0.00132	0.085	0.000	0.10%
Operators skills*Buffer capacity*Vehicle speed	-0.00053	-0.00027	-0.017	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.0004	-0.0002	-0.013	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00174	-0.00087	-0.056	0.000	0.05%
Operators skills*Number of vehicles*Vehicle speed	0.00164	0.00082	0.052	0.000	0.04%
Operators skills*Number of vehicles*Loading capacity	-0.0004	-0.0002	-0.013	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00057	-0.00029	-0.018	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	-0.00028	-0.00014	-0.009	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00019	0.0001	0.006	0.000	0.00%
Operators skills*Loading capacity*Set up duration	-0.00028	-0.00014	-0.009	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00055	-0.00027	-0.018	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00004	-0.00002	-0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00002	0.00001	0.001	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00024	-0.00012	-0.008	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00062	0.00031	0.020	0.000	0.01%
Buffer capacity*Loading capacity*Set up duration	-0.00024	-0.00012	-0.008	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00111	0.00055	0.036	0.000	0.02%
Number of vehicles*Vehicle speed*Set up duration	-0.00189	-0.00094	-0.060	0.000	0.05%
Number of vehicles*Loading capacity*Set up duration	-0.00002	-0.00001	-0.001	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	-0.00035	-0.00017	-0.011	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00052	0.00026	0.017	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00014	0.00007	0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.00013	0.00007	0.004	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00018	0.00009	0.006	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00067	-0.00033	-0.021	0.000	0.01%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00032	0.00016	0.010	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00058	0.00029	0.019	0.000	0.01%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00017	-0.00008	-0.005	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	0.0004	0.0002	0.013	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00056	0.00028	0.018	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.0001	-0.00005	-0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00073	-0.00037	-0.023	0.000	0.01%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00033	0.00017	0.011	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00033	0.00016	0.011	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00003	0.00001	0.001	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00003	-0.00001	-0.001	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00069	0.00035	0.022	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00035	-0.00017	-0.011	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00032	-0.00016	-0.010	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00027	-0.00014	-0.009	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00044	-0.00022	-0.014	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00004	0.00002	0.013	0.000	0.00%
TOTAL				0.107	100%

APPENDIX 27

ANOVA TABLE FOR THE RESPONSE TIME; OPERATOR UNAVAILABILITY SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.076130	0.076130	4999.58	0.000*
Buffer capacity	1	0.003489	0.003489	229.15	0.000*
Number of vehicles	1	0.000091	0.000091	5.97	0.018
Vehicle speed	1	0.002846	0.002846	186.90	0.000*
Set up duration	1	0.018487	0.018487	1214.06	0.000*
Operator skills*Buffer capacity	1	0.003524	0.003524	231.40	0.000*
Operator skills*Number of vehicles	1	0.000357	0.000357	23.44	0.000*
Operator skills*Set up duration	1	0.000954	0.000954	62.64	0.000*
Number of vehicles*Vehicle speed	1	0.000325	0.000325	21.33	0.000*
Vehicle speed*Set up duration	1	0.000158	0.000158	10.37	0.002*
Error	53	0.000807	0.000015		
Total	63	0.107168			

S = 0.00390223 R-Sq = 99.25% R-Sq(adj) = 99.10%

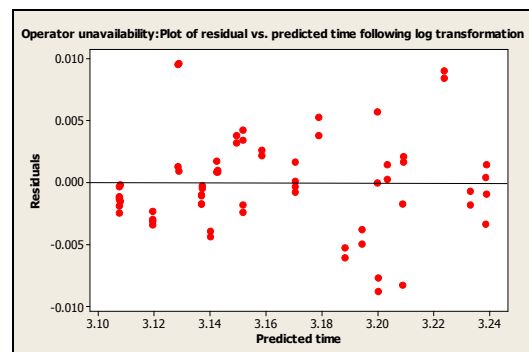
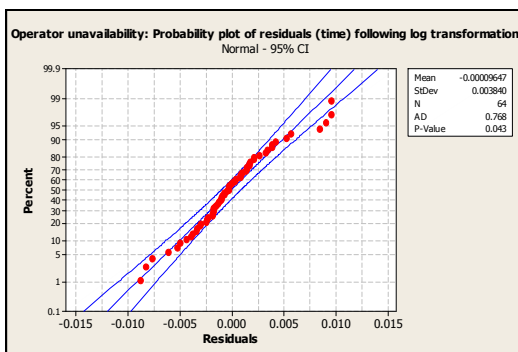
* Significant factors

APPENDIX 28

FREQUENT OPERATOR UNAVAILABILITY SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM

Run	y	\hat{y}	e=y- \hat{y}
(1)	3.1720	3.1703	0.0017
a	3.1295	3.1286	0.0009
b	3.1999	3.1999	0.0000
ab	3.1298	3.1285	0.0013
c	3.1706	3.1705	0.0001
ac	3.1160	3.1193	-0.0033
bc	3.1913	3.2001	-0.0088
abc	3.1162	3.1193	-0.0031
d	3.1525	3.1493	0.0032
ad	3.1061	3.1076	-0.0014
bd	3.1827	3.1789	0.0038
abd	3.1063	3.1075	-0.0012
cd	3.1607	3.1585	0.0022
acd	3.1050	3.1074	-0.0024
bcd	3.1821	3.1881	-0.0060
abcd	3.1054	3.1073	-0.0019
e	3.1696	3.1703	-0.0007
ae	3.1382	3.1286	0.0096
be	3.2056	3.1999	0.0057
abe	3.1381	3.1285	0.0096
ce	3.1702	3.1705	-0.0003
ace	3.1164	3.1193	-0.0030
bce	3.1924	3.2001	-0.0076
abce	3.1170	3.1193	-0.0023
de	3.1531	3.1493	0.0039
ade	3.1074	3.1076	-0.0002
bde	3.1841	3.1789	0.0053
abde	3.1072	3.1075	-0.0003
cde	3.1612	3.1585	0.0027
acde	3.1060	3.1074	-0.0013
bcde	3.1829	3.1881	-0.0052
abcde	3.1062	3.1073	-0.0011

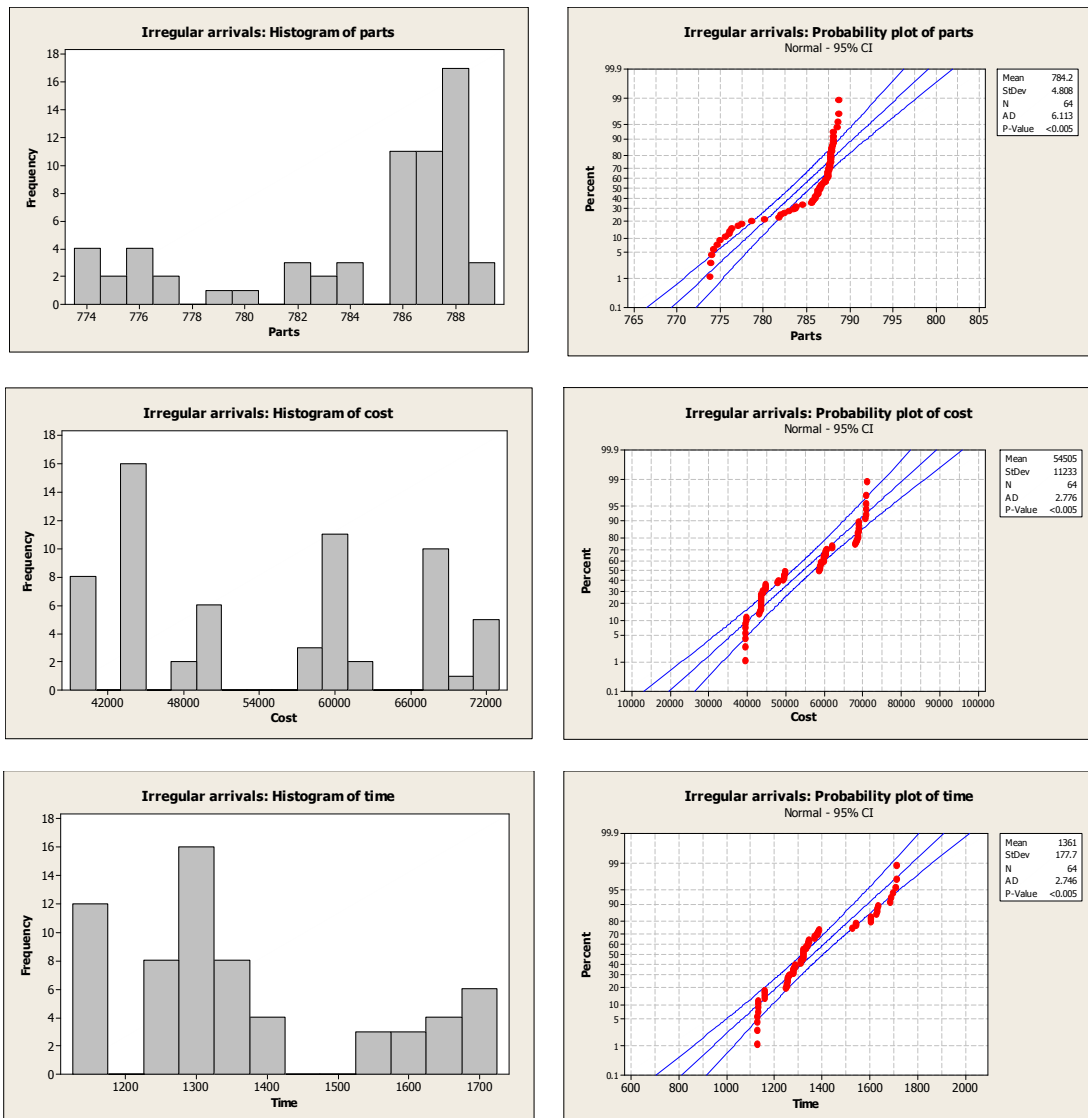
Run	y	\hat{y}	e=y- \hat{y}
f	3.2006	3.2088	-0.0083
af	3.1499	3.1517	-0.0018
bf	3.2352	3.2384	-0.0033
abf	3.1493	3.1516	-0.0023
cf	3.2112	3.2091	0.0022
acf	3.1433	3.1425	0.0009
bcf	3.2378	3.2387	-0.0009
abcf	3.1433	3.1424	0.0009
df	3.1904	3.1941	-0.0037
adf	3.1365	3.1370	-0.0005
bdf	3.2322	3.2237	0.0085
abdf	3.1356	3.1399	-0.0044
cdf	3.2048	3.2034	0.0015
acdf	3.1351	3.1368	-0.0017
bcdf	3.2323	3.2330	-0.0007
abcdf	3.1350	3.1367	-0.0017
ef	3.2071	3.2088	-0.0017
aef	3.1560	3.1517	0.0043
bef	3.2389	3.2384	0.0005
abef	3.1551	3.1516	0.0035
cef	3.2108	3.2091	0.0017
acef	3.1435	3.1425	0.0010
bcef	3.2402	3.2387	0.0015
abcef	3.1442	3.1424	0.0018
def	3.1892	3.1941	-0.0049
adef	3.1368	3.1370	-0.0002
bdef	3.2328	3.2237	0.0090
abdef	3.1360	3.1399	-0.0039
cdef	3.2037	3.2034	0.0003
acdef	3.1358	3.1368	-0.0009
bcdef	3.2312	3.2330	-0.0018
abcdef	3.1357	3.1367	-0.0010



APPENDIX 29

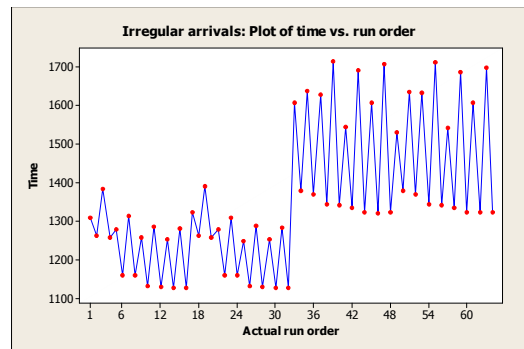
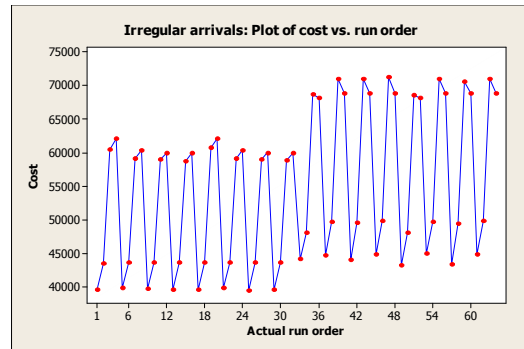
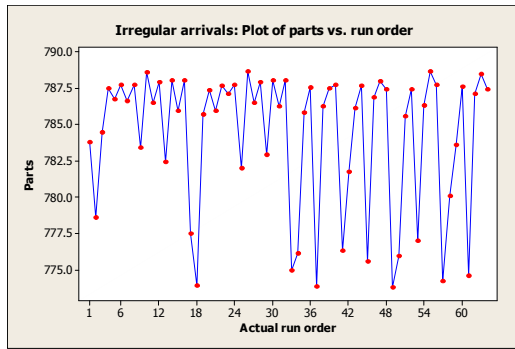
IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: EXPLORATORY DATA ANALYSIS

The histograms and probability plots show that none of the three responses display a normally distributed behaviour; therefore data transformation may be required for the three responses in this scenario.

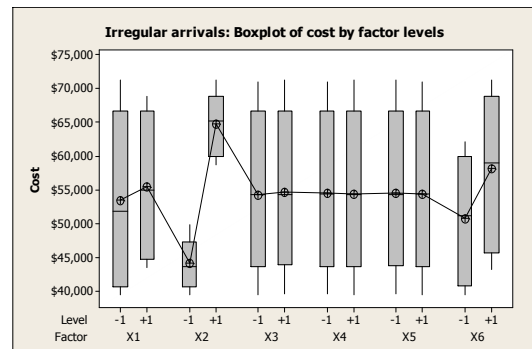
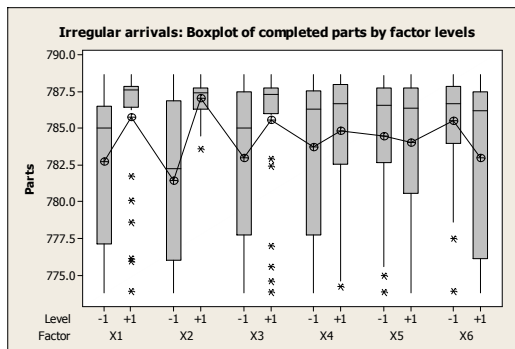


Time series plots do not show any relationship between the sequence of the experiments and the level of the three responses.

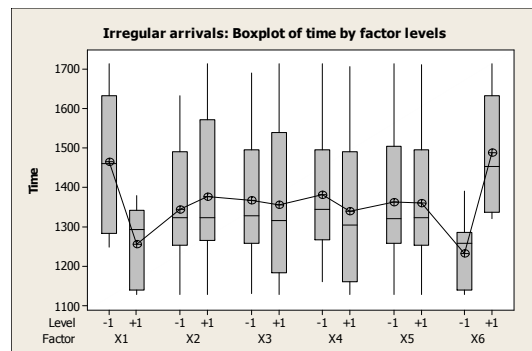
APPENDIX 29 (continued)



Box plots show that factors X1 (skill level of operators) and X2 (buffer capacity) may be a significant factor in terms of throughput. Factors X2 and X6 (duration of set ups) produce an important change in the response average cost. And, in terms of average time in the system, factors X1 (skill level of operators) and X6 (duration of set ups) may be the significant factors.



Factors	
X1:	Skill level of operators
X2:	Buffer capacity
X3:	Number of AVGs
X4:	Speed of AVGs
X5:	Loading capacity of AVGs
X6:	Duration of set-ups



APPENDIX 30

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		784.448			
Operators skills	3.034	1.517	97.088	147.282	11.52%
Buffer capacity	5.16	2.58	165.120	426.010	33.32%
Number of vehicles	2.352	1.176	75.264	88.510	6.92%
Vehicle speed	0.868	0.434	27.776	12.055	0.94%
Loading capacity	-0.231	-0.115	-7.392	0.854	0.07%
Set up duration	-2.616	-1.308	-83.712	109.495	8.56%
Operators skills*Buffer capacity	-1.783	-0.892	-57.056	50.865	3.98%
Operators skills*Number of vehicles	0.661	0.331	21.152	6.991	0.55%
Operators skills*Vehicle speed	1.414	0.707	45.248	31.990	2.50%
Operators skills>Loading capacity	0.264	0.132	8.448	1.115	0.09%
Operators skills*Set up duration	1.133	0.567	36.256	20.539	1.61%
Buffer capacity*Number of vehicles	-1.413	-0.706	-45.216	31.945	2.50%
Buffer capacity*Vehicle speed	-0.788	-0.394	-25.216	9.935	0.78%
Buffer capacity>Loading capacity	0.276	0.138	8.832	1.219	0.10%
Buffer capacity*Set up duration	2.812	1.406	89.984	126.518	9.89%
Number of vehicles*Vehicle speed	-1.508	-0.754	-48.256	36.385	2.85%
Number of vehicles>Loading capacity	0.315	0.158	10.080	1.588	0.12%
Number of vehicles*Set up duration	0.54	0.27	17.280	4.666	0.36%
Vehicle speed>Loading capacity	-0.035	-0.017	-1.120	0.020	0.00%
Vehicle speed*Set up duration	-0.22	-0.11	-7.040	0.774	0.06%
Loading capacity*Set up duration	-0.033	-0.017	-1.056	0.017	0.00%
Operators skills*Buffer capacity*Number of vehicles	-1.497	-0.749	-47.904	35.856	2.80%
Operators skills*Buffer capacity*Vehicle speed	-1.332	-0.666	-42.624	28.388	2.22%
Operators skills*Buffer capacity>Loading capacity	-0.341	-0.17	-10.912	1.860	0.15%
Operators skills*Buffer capacity*Set up duration	-1.528	-0.764	-48.896	37.357	2.92%
Operators skills*Number of vehicles*Vehicle speed	-0.509	-0.254	-16.288	4.145	0.32%
Operators skills*Number of vehicles>Loading capacity	-0.323	-0.161	-10.336	1.669	0.13%
Operators skills*Number of vehicles*Set up duration	0.184	0.092	5.888	0.542	0.04%
Operators skills*Vehicle speed>Loading capacity	0.185	0.092	5.920	0.548	0.04%
Operators skills*Vehicle speed*Set up duration	-0.341	-0.171	-10.912	1.860	0.15%
Operators skills>Loading capacity*Set up duration	0.147	0.073	4.704	0.346	0.03%
Buffer capacity*Number of vehicles*Vehicle speed	1.295	0.647	41.440	26.832	2.10%
Buffer capacity*Number of vehicles>Loading capacity	-0.049	-0.025	-1.568	0.038	0.00%
Buffer capacity*Number of vehicles*Set up duration	-0.044	-0.022	-1.408	0.031	0.00%
Buffer capacity*Vehicle speed>Loading capacity	-0.232	-0.116	-7.424	0.861	0.07%
Buffer capacity*Vehicle speed*Set up duration	-0.049	-0.024	-1.568	0.038	0.00%
Buffer capacity>Loading capacity*Set up duration	-0.157	-0.078	-5.024	0.394	0.03%
Number of vehicles*Vehicle speed>Loading capacity	0.019	0.01	0.608	0.006	0.00%
Number of vehicles*Vehicle speed*Set up duration	0.531	0.266	16.992	4.511	0.35%
Number of vehicles>Loading capacity*Set up duration	0.062	0.031	1.984	0.062	0.00%
Vehicle speed>Loading capacity*Set up duration	-0.168	-0.084	-5.376	0.452	0.04%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.574	0.287	18.368	5.272	0.41%
Operators skills*Buffer capacity*Number of vehicles>Loading capacity	0.087	0.043	2.784	0.121	0.01%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.772	-0.386	-24.704	9.536	0.75%
Operators skills*Buffer capacity*Vehicle speed>Loading capacity	0.105	0.052	3.360	0.176	0.01%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	0.393	0.197	12.576	2.471	0.19%
Operators skills*Buffer capacity>Loading capacity*Set up duration	0.046	0.023	1.472	0.034	0.00%
Operators skills*Number of vehicles*Vehicle speed>Loading capacity	-0.131	-0.065	-4.192	0.275	0.02%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.013	-0.006	-0.416	0.003	0.00%
Operators skills*Number of vehicles>Loading capacity*Set up duration	-0.131	-0.066	-4.192	0.275	0.02%
Operators skills*Vehicle speed>Loading capacity*Set up duration	0.217	0.109	6.944	0.753	0.06%
Buffer capacity*Number of vehicles*Vehicle speed>Loading capacity	0.131	0.066	4.192	0.275	0.02%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.174	-0.087	-5.568	0.484	0.04%
Buffer capacity*Number of vehicles>Loading capacity*Set up duration	0.238	0.119	7.616	0.906	0.07%
Buffer capacity*Vehicle speed>Loading capacity*Set up duration	0.06	0.03	1.920	0.058	0.00%
Number of vehicles*Vehicle speed>Loading capacity*Set up duration	0.003	0.001	0.096	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed>Loading capacity	-0.041	-0.02	-1.312	0.027	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.413	-0.207	-13.216	2.729	0.21%
Operators skills*Buffer capacity*Number of vehicles>Loading capacity*Set up duration	-0.169	-0.085	-5.408	0.457	0.04%
Operators skills*Buffer capacity*Vehicle speed>Loading capacity*Set up duration	-0.122	-0.061	-3.904	0.238	0.02%
Operators skills*Number of vehicles*Vehicle speed>Loading capacity*Set up duration	-0.038	-0.019	-1.216	0.023	0.00%
Buffer capacity*Number of vehicles*Vehicle speed>Loading capacity*Set up duration	0.037	0.019	1.184	0.022	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed>Loading capacity	0.008	0.004	0.256	0.001	0.00%
TOTAL				1278.706	100%

APPENDIX 31

ANOVA TABLE FOR THE RESPONSE NUMBER OF PARTS; IRREG. ARRIVAL OF MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	147.235	147.235	213.66	0.000*
Buffer capacity	1	425.998	425.998	618.18	0.000*
Number of vehicles	1	88.477	88.477	128.39	0.000*
Vehicle speed	1	12.056	12.056	17.50	0.000*
Set up duration	1	109.464	109.464	158.85	0.000*
Operator skills*Buffer capacity	1	50.887	50.887	73.84	0.000*
Operator skills*Number of vehicles	1	6.997	6.997	10.15	0.003*
Operator skills*Vehicle speed	1	31.981	31.981	46.41	0.000*
Operator skills*Set up duration	1	20.545	20.545	29.81	0.000*
Buffer capacity*Number of vehicles	1	31.927	31.927	46.33	0.000*
Buffer capacity*Vehicle speed	1	9.938	9.938	14.42	0.000*
Buffer capacity*Set up duration	1	126.527	126.527	183.61	0.000*
Number of vehicles*Vehicle speed	1	36.386	36.386	52.80	0.000*
Number of vehicles*Set up duration	1	4.669	4.669	6.78	0.013
Operator skills*Buffer capacity* Number of vehicles	1	35.869	35.869	52.05	0.000*
Operator skills*Buffer capacity* Vehicle speed	1	28.375	28.375	41.18	0.000*
Operator skills*Buffer capacity* Set up duration	1	37.340	37.340	54.19	0.000*
Buffer capacity*Number of vehicles* Vehicle speed	1	26.815	26.815	38.91	0.000*
Operator skills*Number of vehicles* Vehicle speed	1	4.137	4.137	6.00	0.019
Operator skills*Buffer capacity* Number of vehicles*Vehicle speed	1	5.270	5.270	7.65	0.009*
Operator skills*Number of vehicles* Set up duration	1	0.540	0.540	0.78	0.381
Buffer capacity*Number of vehicles* Set up duration	1	0.031	0.031	0.05	0.832
Operator skills*Buffer capacity* Number of vehicles*Set up duration	1	9.529	9.529	13.83	0.001*
Error	40	27.565	0.689		
Total	63	1278.560			

S = 0.830128 R-Sq = 97.84% R-Sq(adj) = 96.60%

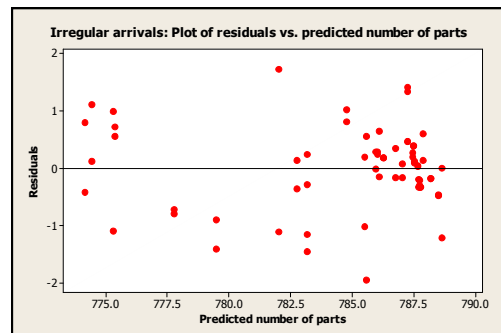
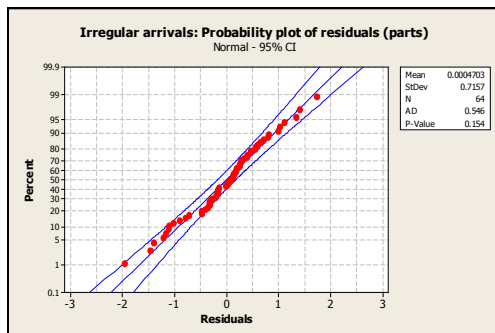
* Significant factors

APPENDIX 32

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	e=y- \hat{y}
(1)	783.7500	782.0170	1.7330
a	778.5738	779.4650	-0.8912
b	784.4682	785.4830	-1.0148
ab	787.4920	787.6830	-0.1910
c	786.7303	786.0810	0.6493
ac	787.7328	787.4530	0.2798
bc	786.5720	786.7350	-0.1630
abc	787.7040	787.6590	0.0450
d	783.4051	783.1550	0.2501
ad	788.5830	787.2430	1.3400
bd	786.4545	786.2690	0.1855
abd	787.8840	787.4850	0.3990
cd	782.4013	782.7630	-0.3617
acd	788.0040	788.4790	-0.4750
bcd	785.9292	785.9450	-0.0158
abcd	788.0000	788.1810	-0.1810
e	780.9091	782.0170	-1.1079
ae	778.0652	779.4650	-1.3998
be	785.6769	785.4830	0.1939
abe	787.3600	787.6830	-0.3230
ce	785.9329	786.0810	-0.1481
ace	787.6545	787.4530	0.2015
bce	787.0785	786.7350	0.3435
abce	787.6960	787.6590	0.0370
de	782.0000	783.1550	-1.1550
ade	788.6538	787.2430	1.4108
bde	786.4502	786.2690	0.1812
abde	787.8840	787.4850	0.3990
cde	782.9060	782.7630	0.1430
acde	788.0161	788.4790	-0.4629
bcde	786.2336	785.9450	0.2886
abcde	788.0000	788.1810	-0.1810

Run	y	\hat{y}	e=y- \hat{y}
f	774.9583	774.1590	0.7993
af	776.1076	775.3870	0.7206
bf	785.7877	784.7610	1.0267
abf	787.5080	787.7170	-0.2090
cf	777.0385	777.7590	-0.7205
acf	786.2500	785.9990	0.2510
bcf	787.4335	788.6370	-1.2035
abcf	787.6960	787.2290	0.4670
df	776.2857	775.2970	0.9887
adf	781.7120	783.1650	-1.4530
bdf	786.1133	785.5470	0.5663
abdf	787.6480	787.5190	0.1290
cdf	775.5568	774.4410	1.1158
acdf	786.8607	787.0250	-0.1643
bcdf	787.9828	787.8470	0.1358
abcdf	787.4240	787.7510	-0.3270
ef	773.7500	774.1590	-0.4090
aef	775.9423	775.3870	0.5553
bef	785.5775	784.7610	0.8165
abef	787.4280	787.7170	-0.2890
cef	776.9688	777.7590	-0.7903
acef	786.2828	785.9990	0.2838
bcef	788.6414	788.6370	0.0044
abcef	787.6960	787.2290	0.4670
def	774.2000	775.2970	-1.0970
adef	782.8870	783.1650	-0.2780
bdef	783.5990	785.5470	-1.9480
abdef	787.6120	787.5190	0.0930
cdef	774.5682	774.4410	0.1272
acdef	787.1057	787.0250	0.0807
bcdef	788.4557	787.8470	0.6087
abcdef	787.4240	787.7510	-0.3270



APPENDIX 33

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.72736			
Operators skills	0.02149	0.01074	0.688	0.007	1.44%
Buffer capacity	0.16607	0.08303	5.314	0.441	86.11%
Number of vehicles	0.00238	0.00119	0.076	0.000	0.02%
Vehicle speed	-0.00027	-0.00013	-0.009	0.000	0.00%
Loading capacity	-0.00063	-0.00031	-0.020	0.000	0.00%
Set up duration	0.05736	0.02868	1.836	0.053	10.27%
Operators skills*Buffer capacity	-0.02239	-0.01119	-0.716	0.008	1.57%
Operators skills*Number of vehicles	-0.00154	-0.00077	-0.049	0.000	0.01%
Operators skills*Vehicle speed	0.00036	0.00018	0.012	0.000	0.00%
Operators skills*Loading capacity	0.00073	0.00037	0.023	0.000	0.00%
Operators skills*Set up duration	-0.00344	-0.00172	-0.110	0.000	0.04%
Buffer capacity*Number of vehicles	-0.00285	-0.00142	-0.091	0.000	0.03%
Buffer capacity*Vehicle speed	-0.0013	-0.00065	-0.042	0.000	0.01%
Buffer capacity*Loading capacity	0.00047	0.00023	0.015	0.000	0.00%
Buffer capacity*Set up duration	0.00701	0.0035	0.224	0.001	0.15%
Number of vehicles*Vehicle speed	-0.00063	-0.00031	-0.020	0.000	0.00%
Number of vehicles*Loading capacity	0.00053	0.00026	0.017	0.000	0.00%
Number of vehicles*Set up duration	0.00526	0.00263	0.168	0.000	0.09%
Vehicle speed*Loading capacity	-0.00011	-0.00006	-0.004	0.000	0.00%
Vehicle speed*Set up duration	0.00429	0.00214	0.137	0.000	0.06%
Loading capacity*Set up duration	-0.00074	-0.00037	-0.024	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles	-0.00003	-0.00015	-0.010	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00198	-0.00099	-0.063	0.000	0.01%
Operators skills*Buffer capacity*Loading capacity	-0.00065	-0.00032	-0.021	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00617	-0.00308	-0.197	0.001	0.12%
Operators skills*Number of vehicles*Vehicle speed	0.0002	0.0001	0.006	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	-0.0006	-0.0003	-0.019	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00084	-0.00042	-0.027	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	0.00006	0.00003	0.002	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00041	0.00021	0.013	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00058	0.00029	0.019	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	0.0012	0.0006	0.038	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00053	-0.00026	-0.017	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00048	0.00024	0.015	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00008	-0.00004	-0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00202	0.00101	0.065	0.000	0.01%
Buffer capacity*Loading capacity*Set up duration	0.00035	0.00017	0.011	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00012	0.00006	0.004	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00303	-0.00152	-0.097	0.000	0.03%
Number of vehicles*Loading capacity*Set up duration	0.00067	0.00034	0.021	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	0.00021	0.0001	0.007	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00129	0.00065	0.041	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00068	0.00034	0.022	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.00049	-0.00024	-0.016	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00021	0.00011	0.007	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00118	-0.00059	-0.038	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.00021	-0.00011	-0.007	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.00002	-0.00001	-0.001	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00047	-0.00023	-0.015	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00047	-0.00024	-0.015	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00001	-0.00001	0.000	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0	0	0.000	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00178	-0.00089	-0.057	0.000	0.01%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00048	-0.00024	-0.015	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00032	-0.00016	-0.010	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00036	-0.00018	-0.012	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00017	-0.00009	-0.005	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00114	0.00057	0.036	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.0003	0.00015	0.010	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00014	0.00007	0.004	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00018	0.00009	0.006	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00022	0.00011	0.007	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00005	-0.00003	-0.002	0.000	0.00%
TOTAL				0.512	100%

APPENDIX 34

ANOVA TABLE FOR THE RESPONSE COST, IRREGULAR ARRIVALS OF MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.007388	0.007388	521.53	0.000*
Buffer capacity	1	0.441267	0.441267	31151.52	0.000*
Number of vehicles	1	0.000091	0.000091	6.42	0.014
Vehicle speed	1	0.000001	0.000001	0.08	0.777
Set up duration	1	0.052641	0.052641	3716.25	0.000*
Operator skills*Buffer capacity	1	0.008019	0.008019	566.11	0.000*
Operator skills*Set up duration	1	0.000189	0.000189	13.35	0.001*
Buffer capacity*Set up duration	1	0.000785	0.000785	55.45	0.000*
Number of vehicles*Set up duration	1	0.000442	0.000442	31.20	0.000*
Vehicle speed*Set up duration	1	0.000294	0.000294	20.74	0.000*
Operator skills*Buffer capacity* Set up duration	1	0.000609	0.000609	43.00	0.000*
Error	52	0.000737	0.000014		
Total	63	0.512463			

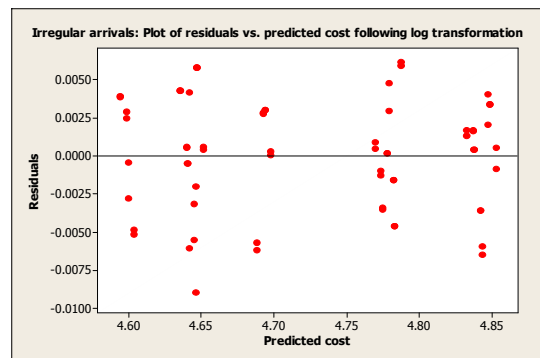
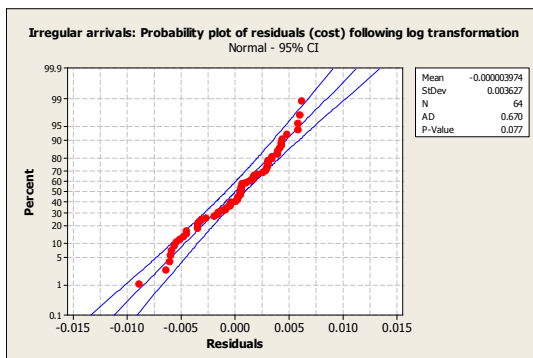
S = 0.00376367 R-Sq = 99.86% R-Sq(adj) = 99.83%

* Significant factors

APPENDIX 35

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: RESIDUALS FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	4.5982	4.6034	-0.0052	f	4.6456	4.6415	0.0042
a	4.6390	4.6445	-0.0055	af	4.6823	4.6880	-0.0057
b	4.7816	4.7786	0.0030	bf	4.8371	4.8431	-0.0059
ab	4.7935	4.7873	0.0062	abf	4.8342	4.8326	0.0017
c	4.6010	4.5981	0.0029	cf	4.6525	4.6467	0.0058
ac	4.6398	4.6392	0.0006	acf	4.6963	4.6933	0.0030
bc	4.7724	4.7734	-0.0010	bcf	4.8517	4.8483	0.0034
abc	4.7805	4.7821	-0.0016	abcf	4.8382	4.8378	0.0004
d	4.5986	4.5991	-0.0004	df	4.6437	4.6457	-0.0020
ad	4.6397	4.6402	-0.0005	adf	4.6951	4.6923	0.0028
bd	4.7708	4.7744	-0.0035	bdf	4.8514	4.8473	0.0041
abd	4.7785	4.7831	-0.0046	abdf	4.8385	4.8368	0.0017
cd	4.5977	4.5938	0.0039	cdf	4.6516	4.6510	0.0006
acd	4.6392	4.6350	0.0043	acdf	4.6976	4.6976	0.0000
bcd	4.7696	4.7691	0.0005	bcdf	4.8531	4.8526	0.0005
abcd	4.7779	4.7778	0.0002	abcdf	4.8385	4.8421	-0.0036
e	4.5985	4.6034	-0.0048	ef	4.6354	4.6415	-0.0060
ae	4.6413	4.6445	-0.0032	aef	4.6819	4.6880	-0.0062
be	4.7834	4.7786	0.0048	bef	4.8366	4.8431	-0.0065
abe	4.7933	4.7873	0.0059	abef	4.8339	4.8326	0.0013
ce	4.6006	4.5981	0.0025	cef	4.6525	4.6467	0.0058
ace	4.6397	4.6392	0.0005	acef	4.6963	4.6933	0.0030
bce	4.7721	4.7734	-0.0013	bcef	4.8517	4.8483	0.0033
abce	4.7805	4.7821	-0.0016	abcef	4.8382	4.8378	0.0004
de	4.5963	4.5991	-0.0028	def	4.6368	4.6457	-0.0089
ade	4.6397	4.6402	-0.0005	def	4.6951	4.6923	0.0028
bde	4.7710	4.7744	-0.0034	bdef	4.8494	4.8473	0.0020
abde	4.7785	4.7831	-0.0046	abdef	4.8385	4.8368	0.0016
cde	4.5977	4.5938	0.0039	cdef	4.6514	4.6510	0.0004
acde	4.6392	4.6350	0.0043	acdef	4.6979	4.6976	0.0003
bcde	4.7700	4.7691	0.0009	bcdef	4.8517	4.8526	-0.0009
abcde	4.7780	4.7778	0.0002	abcdef	4.8385	4.8421	-0.0036



APPENDIX 36

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.13019			
Operators skills	-0.0651	-0.03255	-2.083	0.068	35.47%
Buffer capacity	0.00932	0.00466	0.298	0.001	0.73%
Number of vehicles	-0.00479	-0.00239	-0.153	0.000	0.19%
Vehicle speed	-0.01477	-0.00739	-0.473	0.003	1.83%
Loading capacity	-0.00071	-0.00036	-0.023	0.000	0.00%
Set up duration	0.08022	0.04011	2.567	0.103	53.87%
Operators skills*Buffer capacity	-0.01045	-0.00523	-0.334	0.002	0.91%
Operators skills*Number of vehicles	-0.00728	-0.00364	-0.233	0.001	0.44%
Operators skills*Vehicle speed	-0.00533	-0.00267	-0.171	0.000	0.24%
Operators skills*Loading capacity	0.00058	0.00029	0.019	0.000	0.00%
Operators skills*Set up duration	-0.0205	-0.01025	-0.656	0.007	3.52%
Buffer capacity*Number of vehicles	-0.00098	-0.00049	-0.031	0.000	0.01%
Buffer capacity*Vehicle speed	0.00089	0.00045	0.028	0.000	0.01%
Buffer capacity*Loading capacity	0.00049	0.00025	0.016	0.000	0.00%
Buffer capacity*Set up duration	0.00281	0.0014	0.090	0.000	0.07%
Number of vehicles*Vehicle speed	0.00649	0.00325	0.208	0.001	0.35%
Number of vehicles*Loading capacity	0.0006	0.0003	0.019	0.000	0.00%
Number of vehicles*Set up duration	0.00922	0.00461	0.295	0.001	0.71%
Vehicle speed*Loading capacity	0.00025	0.00012	0.008	0.000	0.00%
Vehicle speed*Set up duration	0.00905	0.00452	0.290	0.001	0.69%
Loading capacity*Set up duration	-0.00095	-0.00047	-0.030	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles	0.00195	0.00098	0.062	0.000	0.03%
Operators skills*Buffer capacity*Vehicle speed	-0.00081	-0.00041	-0.026	0.000	0.01%
Operators skills*Buffer capacity*Loading capacity	-0.00047	-0.00024	-0.015	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00349	-0.00174	-0.112	0.000	0.10%
Operators skills*Number of vehicles*Vehicle speed	0.00402	0.00201	0.129	0.000	0.14%
Operators skills*Number of vehicles*Loading capacity	-0.00044	-0.00022	-0.014	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00303	-0.00152	-0.097	0.000	0.08%
Operators skills*Vehicle speed*Loading capacity	-0.00027	-0.00013	-0.009	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00018	0.00009	0.006	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00009	0.00005	0.029	0.000	0.01%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00045	-0.00022	-0.014	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00073	-0.00036	-0.023	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00042	0.00021	0.013	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00032	-0.00016	-0.010	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00218	0.00109	0.070	0.000	0.04%
Buffer capacity*Loading capacity*Set up duration	0.00055	0.00028	0.018	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	-0.00035	-0.00017	-0.011	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00649	-0.00325	-0.208	0.001	0.35%
Number of vehicles*Loading capacity*Set up duration	0.00092	0.00046	0.029	0.000	0.01%
Vehicle speed*Loading capacity*Set up duration	0.00075	0.00038	0.024	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00045	0.00023	0.014	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00068	0.00034	0.022	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.0002	0.0001	0.006	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00045	0.00023	0.014	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00228	-0.00114	-0.073	0.000	0.04%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.00051	-0.00025	-0.016	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00037	0.00019	0.012	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00004	-0.00002	-0.001	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00086	-0.00043	-0.028	0.000	0.01%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00084	-0.00042	-0.027	0.000	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00039	0.0002	0.012	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00149	-0.00075	-0.048	0.000	0.02%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00082	-0.00041	-0.026	0.000	0.01%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00091	-0.00046	-0.029	0.000	0.01%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00107	-0.00054	-0.034	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00053	-0.00027	-0.017	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00176	0.00088	0.056	0.000	0.03%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00076	0.00038	0.024	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.001	0.0005	0.032	0.000	0.01%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00117	0.00058	0.037	0.000	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00076	0.00038	0.024	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00086	-0.00043	-0.028	0.000	0.01%
TOTAL				0.191	100%

APPENDIX 37

ANOVA TABLE FOR THE RESPONSE TIME; IRREGULAR ARRIVALS OF MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.067812	0.067812	2535.35	0.000*
Buffer capacity	1	0.001391	0.001391	52.00	0.000*
Number of vehicles	1	0.000367	0.000367	13.72	0.001*
Vehicle speed	1	0.003492	0.003492	130.56	0.000*
Set up duration	1	0.102952	0.102952	3849.14	0.000*
Operator skills*Buffer capacity	1	0.001749	0.001749	65.38	0.000*
Operator skills*Number of vehicles	1	0.000848	0.000848	31.69	0.000*
Operator skills*Vehicle speed	1	0.000455	0.000455	17.00	0.000*
Operator skills*Set up duration	1	0.006727	0.006727	251.52	0.000*
Number of vehicles*Vehicle speed	1	0.000674	0.000674	25.20	0.000*
Number of vehicles*Set up duration	1	0.001361	0.001361	50.87	0.000*
Vehicle speed*Set up duration	1	0.001310	0.001310	48.99	0.000*
Number of vehicles*Vehicle speed*	1	0.000675	0.000675	25.23	0.000*
Set up duration					
Error	50	0.001337	0.000027		
Total	63	0.191149			
S = 0.00517172 R-Sq = 99.30% R-Sq(adj) = 99.12%					

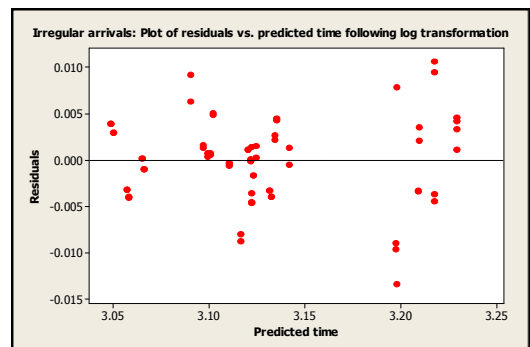
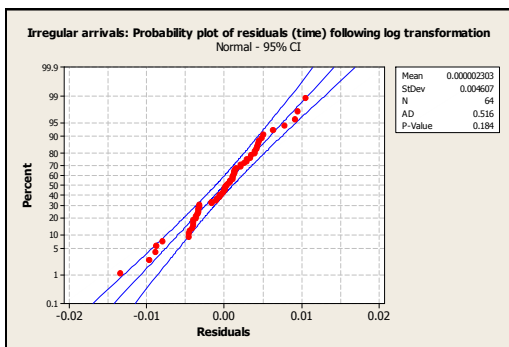
* Significant factors

APPENDIX 38

IRREGULAR PATTERN OF RAW-MATERIAL-ARRIVALS SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}
(1)	3.1170	3.1216	-0.0046
a	3.1008	3.1001	0.0008
b	3.1408	3.1414	-0.0005
ab	3.0997	3.0989	0.0008
c	3.1069	3.1019	0.0051
ac	3.0648	3.0658	-0.0010
bc	3.1181	3.1217	-0.0036
abc	3.0648	3.0647	0.0001
d	3.0993	3.0901	0.0092
ad	3.0540	3.0579	-0.0039
bd	3.1093	3.1099	-0.0006
abd	3.0535	3.0568	-0.0032
cd	3.0980	3.0964	0.0016
acd	3.0526	3.0496	0.0030
bcd	3.1074	3.1162	-0.0088
abcd	3.0524	3.0485	0.0039
e	3.1230	3.1216	0.0014
ae	3.1006	3.1001	0.0006
be	3.1427	3.1414	0.0013
abe	3.0993	3.0989	0.0003
ce	3.1067	3.1019	0.0048
ace	3.0648	3.0658	-0.0010
bce	3.1171	3.1217	-0.0046
abce	3.0648	3.0647	0.0001
de	3.0964	3.0901	0.0063
ade	3.0539	3.0579	-0.0041
bde	3.1095	3.1099	-0.0003
abde	3.0535	3.0568	-0.0032
cde	3.0977	3.0964	0.0013
acde	3.0526	3.0496	0.0030
bcde	3.1082	3.1162	-0.0080
abcde	3.0524	3.0485	0.0039

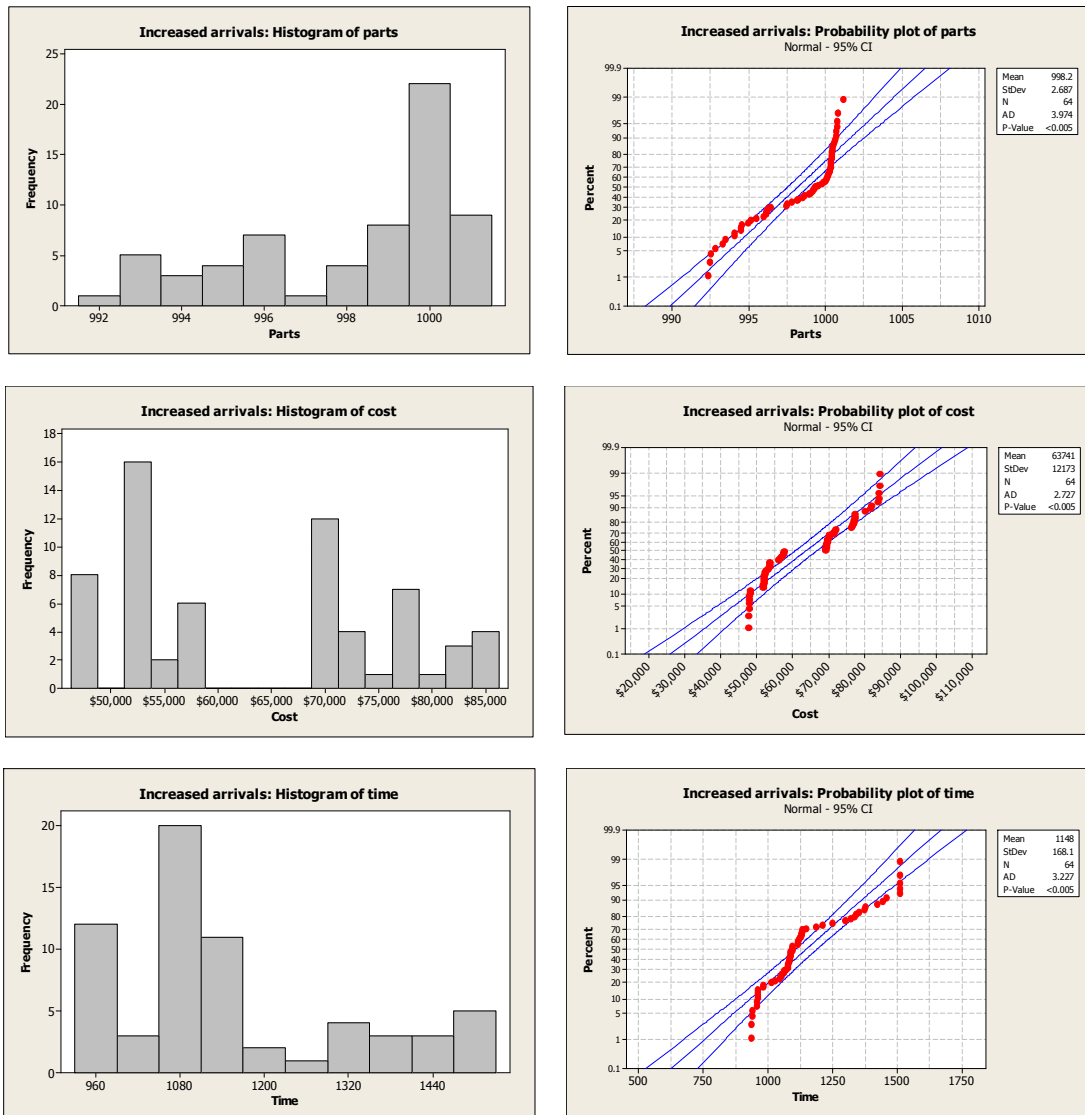
Run	y	\hat{y}	e=y- \hat{y}
f	3.2054	3.1976	0.0079
af	3.1394	3.1350	0.0043
bf	3.2137	3.2173	-0.0037
abf	3.1365	3.1339	0.0027
cf	3.2114	3.2093	0.0021
acf	3.1282	3.1322	-0.0040
bcf	3.2336	3.2291	0.0045
abcf	3.1278	3.1311	-0.0033
df	3.1882	3.1972	-0.0089
adf	3.1255	3.1240	0.0015
bdf	3.2276	3.2169	0.0106
abdf	3.1212	3.1228	-0.0016
cdf	3.2056	3.2089	-0.0033
acdf	3.1210	3.1211	-0.0001
bcdf	3.2320	3.2287	0.0034
abcdf	3.1211	3.1200	0.0012
ef	3.1842	3.1976	-0.0134
aef	3.1395	3.1350	0.0044
bef	3.2129	3.2173	-0.0045
abef	3.1361	3.1339	0.0022
cef	3.2128	3.2093	0.0035
acef	3.1283	3.1322	-0.0039
bcef	3.2333	3.2291	0.0042
abcef	3.1278	3.1311	-0.0033
def	3.1875	3.1972	-0.0096
adef	3.1242	3.1240	0.0003
bdef	3.2264	3.2169	0.0095
abdef	3.1212	3.1228	-0.0016
cdef	3.2055	3.2089	-0.0034
acdef	3.1212	3.1211	0.0001
bcdef	3.2297	3.2287	0.0011
abcdef	3.1211	3.1200	0.0012



APPENDIX 39

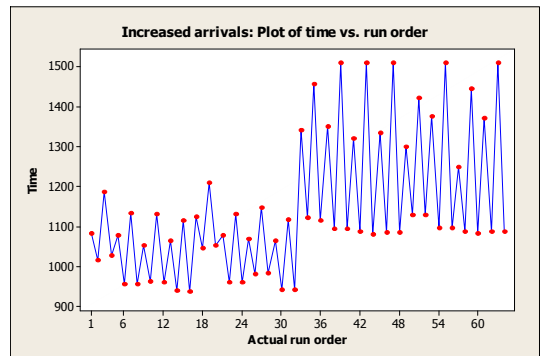
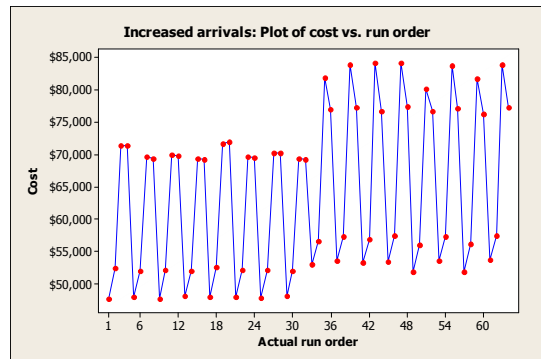
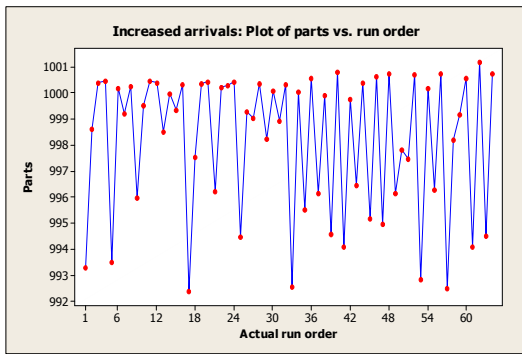
INCREASED ARRIVALS OF RAW MATERIAL SCENARIO: EXPLORATORY DATA ANALYSIS

The histograms and probability plots show that none of the three responses display a normally distributed behaviour; therefore data transformation may be required for the three responses in this scenario.

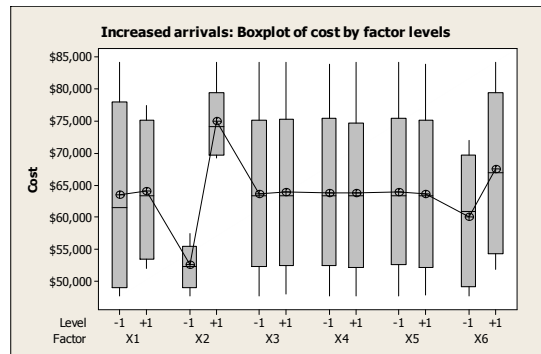
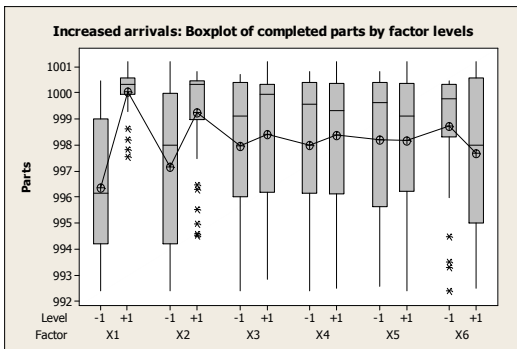


Time series plot in figures do not show any relationship between the sequence of the experiments and the level of the three responses.

APPENDIX 39 (continued)

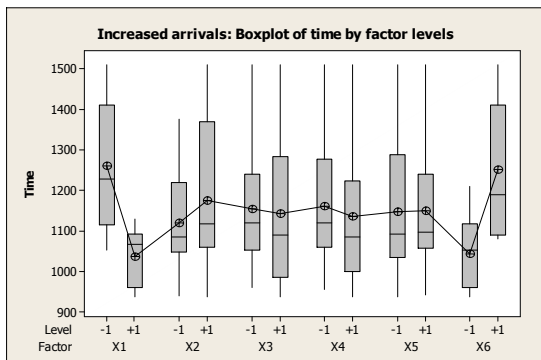


The box plots show that factors X1 (skill level of operators) and X2 (buffer capacity) may be of significance in terms of throughput. Factors X2 and X6 (duration of set ups) produce an important change in the response average cost. And, in terms of average time in the system, factors X1 and X6 may be the significant factors.



Factors

- X1:** Skill level of operators
- X2:** Buffer capacity
- X3:** Number of AVGs
- X4:** Speed of AVGs
- X5:** Loading capacity of AVGs
- X6:** Duration of set-ups



APPENDIX 40

INCREASED ARRIVALS OF RAW-MATERIAL SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		998.194			
Operators skills	3.695	1.847	118.240	218.448	48.02%
Buffer capacity	2.067	1.033	66.144	68.360	15.03%
Number of vehicles	0.454	0.227	14.528	3.298	0.72%
Vehicle speed	0.383	0.192	12.256	2.347	0.52%
Loading capacity	-0.034	-0.017	-1.088	0.018	0.00%
Set up duration	-1.046	-0.523	-33.472	17.506	3.85%
Operators skills*Buffer capacity	-1.121	-0.561	-35.872	20.106	4.42%
Operators skills*Number of vehicles	0.305	0.152	9.760	1.488	0.33%
Operators skills*Vehicle speed	-0.161	-0.081	-5.152	0.415	0.09%
Operators skills*Loading capacity	-0.206	-0.103	-6.592	0.679	0.15%
Operators skills*Set up duration	1.334	0.667	42.688	28.473	6.26%
Buffer capacity*Number of vehicles	-1.098	-0.549	-35.136	19.290	4.24%
Buffer capacity*Vehicle speed	-0.499	-0.249	-15.968	3.984	0.88%
Buffer capacity*Loading capacity	0.375	0.187	12.000	2.250	0.49%
Buffer capacity*Set up duration	-0.622	-0.311	-19.904	6.190	1.36%
Number of vehicles*Vehicle speed	-0.01	-0.005	-0.320	0.002	0.00%
Number of vehicles*Loading capacity	0.098	0.049	3.136	0.154	0.03%
Number of vehicles*Set up duration	-0.356	-0.178	-11.392	2.028	0.45%
Vehicle speed*Loading capacity	-0.278	-0.139	-8.896	1.237	0.27%
Vehicle speed*Set up duration	-0.335	-0.167	-10.720	1.796	0.39%
Loading capacity*Set up duration	0.086	0.043	2.752	0.118	0.03%
Operators skills*Buffer capacity*Number of vehicles	0.406	0.203	12.992	2.637	0.58%
Operators skills*Buffer capacity*Vehicle speed	0.199	0.1	6.368	0.634	0.14%
Operators skills*Buffer capacity*Loading capacity	-0.095	-0.047	-3.040	0.144	0.03%
Operators skills*Buffer capacity*Set up duration	0.627	0.313	20.064	6.290	1.38%
Operators skills*Number of vehicles*Vehicle speed	-0.048	-0.024	-1.536	0.037	0.01%
Operators skills*Number of vehicles*Loading capacity	0.274	0.137	8.768	1.201	0.26%
Operators skills*Number of vehicles*Set up duration	0.463	0.231	14.816	3.430	0.75%
Operators skills*Vehicle speed*Loading capacity	0.393	0.196	12.576	2.471	0.54%
Operators skills*Vehicle speed*Set up duration	0.289	0.145	9.248	1.336	0.29%
Operators skills*Loading capacity*Set up duration	-0.187	-0.094	-5.984	0.560	0.12%
Buffer capacity*Number of vehicles*Vehicle speed	-0.215	-0.107	-6.880	0.740	0.16%
Buffer capacity*Number of vehicles*Loading capacity	-0.185	-0.093	-5.920	0.548	0.12%
Buffer capacity*Number of vehicles*Set up duration	0.063	0.031	2.016	0.064	0.01%
Buffer capacity*Vehicle speed*Loading capacity	0.01	0.005	0.320	0.002	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.553	0.277	17.696	4.893	1.08%
Buffer capacity*Loading capacity*Set up duration	0.346	0.173	11.072	1.915	0.42%
Number of vehicles*Vehicle speed*Loading capacity	0.024	0.012	0.768	0.009	0.00%
Number of vehicles*Vehicle speed*Set up duration	0.026	0.013	0.832	0.011	0.00%
Number of vehicles*Loading capacity*Set up duration	-0.443	-0.222	-14.176	3.140	0.69%
Vehicle speed*Loading capacity*Set up duration	0.076	0.038	2.432	0.092	0.02%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.325	0.163	10.400	1.690	0.37%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.203	-0.102	-6.496	0.659	0.14%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.036	-0.018	-1.152	0.021	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.127	-0.063	-4.064	0.258	0.06%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.534	-0.267	-17.088	4.562	1.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.228	-0.114	-7.296	0.832	0.18%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.1	-0.05	-3.200	0.160	0.04%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.274	0.137	8.768	1.201	0.26%
Operators skills*Number of vehicles*Loading capacity*Set up duration	0.605	0.302	19.360	5.856	1.29%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.057	-0.028	-1.824	0.052	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.219	-0.109	-7.008	0.767	0.17%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.269	-0.135	-8.608	1.158	0.25%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.063	0.032	2.016	0.064	0.01%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.034	0.017	1.088	0.018	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.24	0.12	7.680	0.922	0.20%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.283	0.141	9.056	1.281	0.28%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.008	-0.004	-0.256	0.001	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.297	-0.149	-9.504	1.411	0.31%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.017	-0.009	-0.544	0.005	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.202	-0.101	-6.464	0.653	0.14%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.399	-0.199	-12.768	2.547	0.56%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.389	0.195	12.448	2.421	0.53%
TOTAL				454.880	100%

APPENDIX 41

ANOVA TABLE FOR THE RESPONSE NUMBER OF COMPLETED PARTS; INCREASED ARRIVAL OF MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	218.423	218.423	154.05	0.000*
Buffer capacity	1	68.337	68.337	48.20	0.000*
Number of vehicles	1	3.301	3.301	2.33	0.133
Set up duration	1	17.520	17.520	12.36	0.001*
Operator skills*Buffer capacity	1	20.117	20.117	14.19	0.000*
Operator skills*Set up duration	1	28.457	28.457	20.07	0.000*
Buffer capacity*Number of vehicles	1	19.280	19.280	13.60	0.001*
Error	56	79.401	1.418		
Total	63	454.834			

S = 1.19075 R-Sq = 82.54% R-Sq(adj) = 80.36%

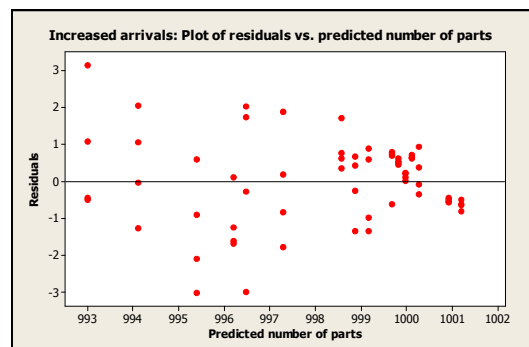
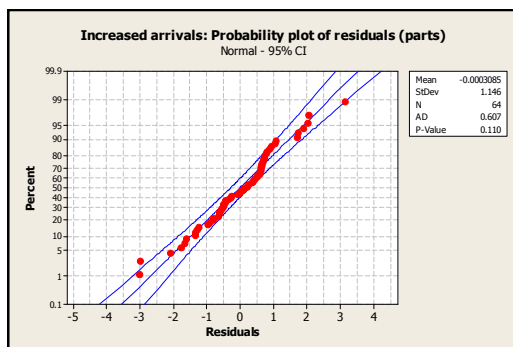
* Significant factors

APPENDIX 42

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	e=y- \hat{y}
(1)	993.3000	995.3940	-2.0940
a	998.6170	998.8760	-0.2590
b	1000.4091	999.6800	0.7291
ab	1000.4600	1000.9180	-0.4580
c	993.4894	996.4920	-3.0026
ac	1000.1792	999.9740	0.2052
bc	999.2065	998.5820	0.6245
abc	1000.2680	999.8200	0.4480
d	995.9750	995.3940	0.5810
ad	999.5328	998.8760	0.6568
bd	1000.4713	999.6800	0.7913
abd	1000.3760	1000.9180	-0.5420
cd	998.5000	996.4920	2.0080
acd	999.9795	999.9740	0.0055
bcd	999.3455	998.5820	0.7635
abcd	1000.3240	999.8200	0.5040
e	992.3750	995.3940	-3.0190
ae	997.5357	998.8760	-1.3403
be	1000.3607	999.6800	0.6807
abe	1000.4240	1000.9180	-0.4940
ce	996.2000	996.4920	-0.2920
ace	1000.2033	999.9740	0.2293
bce	1000.2782	998.5820	1.6962
abce	1000.4240	999.8200	0.6040
de	994.4783	995.3940	-0.9157
ade	999.2828	998.8760	0.4068
bde	999.0492	999.6800	-0.6308
abde	1000.3440	1000.9180	-0.5740
cde	998.2243	996.4920	1.7323
acde	1000.0854	999.9740	0.1114
bcde	998.9187	998.5820	0.3367
abcde	1000.3240	999.8200	0.5040

Run	y	\hat{y}	e=y- \hat{y}
f	992.5556	993.0140	-0.4584
af	1000.0318	999.1640	0.8678
bf	995.5219	997.3000	-1.7781
abf	1000.5840	1001.2060	-0.6220
cf	996.1591	994.1120	2.0471
acf	999.9046	1000.2620	-0.3574
bcf	994.5818	996.2020	-1.6202
abcf	1000.8160	1000.1080	0.7080
df	994.0769	993.0140	1.0629
adf	999.7527	999.1640	0.5887
bdf	996.4690	997.3000	-0.8310
abdf	1000.3880	1001.2060	-0.8180
cdf	995.1538	994.1120	1.0418
acdf	1000.6286	1000.2620	0.3666
bcdf	994.9531	996.2020	-1.2489
abcdf	1000.7360	1000.1080	0.6280
ef	996.1429	993.0140	3.1289
aef	997.8105	999.1640	-1.3535
bef	997.4835	997.3000	0.1835
abef	1000.7120	1001.2060	-0.4940
cef	992.8269	994.1120	-1.2851
acef	1000.1796	1000.2620	-0.0824
bcef	996.2978	996.2020	0.0958
abcef	1000.7320	1000.1080	0.6240
def	992.5000	993.0140	-0.5140
adef	998.1837	999.1640	-0.9803
bdef	999.1757	997.3000	1.8757
abdef	1000.5520	1001.2060	-0.6540
cdef	994.0800	994.1120	-0.0320
acdef	1001.1875	1000.2620	0.9255
bcdef	994.5225	996.2020	-1.6795
abcdef	1000.7560	1000.1080	0.6480



APPENDIX 43

INCREASED ARRIVALS OF RAW-MATERIAL SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.79661			
Operators skills	0.00862	0.00431	0.276	0.001	0.27%
Buffer capacity	0.15432	0.07716	4.938	0.381	87.71%
Number of vehicles	0.0016	0.0008	0.051	0.000	0.01%
Vehicle speed	-0.00073	-0.00037	-0.023	0.000	0.00%
Loading capacity	-0.0013	-0.00065	-0.042	0.000	0.01%
Set up duration	0.04852	0.02426	1.553	0.038	8.67%
Operators skills*Buffer capacity	-0.0251	-0.01255	-0.803	0.010	2.32%
Operators skills*Number of vehicles	-0.0018	-0.0009	-0.058	0.000	0.01%
Operators skills*Vehicle speed	-0.00097	-0.00049	-0.031	0.000	0.00%
Operators skills*Loading capacity	0.00096	0.00048	0.031	0.000	0.00%
Operators skills*Set up duration	-0.00936	-0.00468	-0.300	0.001	0.32%
Buffer capacity*Number of vehicles	-0.00245	-0.00123	-0.078	0.000	0.02%
Buffer capacity*Vehicle speed	-0.00079	-0.0004	-0.025	0.000	0.00%
Buffer capacity*Loading capacity	0.00009	0.00004	0.003	0.000	0.00%
Buffer capacity*Set up duration	0.00796	0.00398	0.255	0.001	0.23%
Number of vehicles*Vehicle speed	0.00081	0.00041	0.026	0.000	0.00%
Number of vehicles*Loading capacity	0.0013	0.00065	0.042	0.000	0.01%
Number of vehicles*Set up duration	0.00585	0.00293	0.187	0.001	0.13%
Vehicle speed*Loading capacity	-0.00025	-0.00012	-0.008	0.000	0.00%
Vehicle speed*Set up duration	0.00245	0.00123	0.078	0.000	0.02%
Loading capacity*Set up duration	-0.0023	-0.00115	-0.074	0.000	0.02%
Operators skills*Buffer capacity*Number of vehicles	-0.00022	-0.00011	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00085	-0.00042	-0.027	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	0.00039	0.0002	0.012	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00645	-0.00323	-0.206	0.001	0.15%
Operators skills*Number of vehicles*Vehicle speed	0.00099	0.00049	0.032	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	-0.00089	-0.00045	-0.028	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00036	-0.00018	-0.012	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	0.00021	0.0001	0.007	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00036	-0.00018	-0.012	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00081	0.00041	0.026	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	0.00041	0.0002	0.013	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.0004	-0.0002	-0.013	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00177	0.00088	0.057	0.000	0.01%
Buffer capacity*Vehicle speed*Loading capacity	-0.00004	-0.00002	-0.001	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00153	0.00077	0.049	0.000	0.01%
Buffer capacity*Loading capacity*Set up duration	-0.00008	-0.00004	-0.003	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00038	0.00019	0.012	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00167	-0.00084	-0.053	0.000	0.01%
Number of vehicles*Loading capacity*Set up duration	0.00225	0.00113	0.072	0.000	0.02%
Vehicle speed*Loading capacity*Set up duration	-0.00006	-0.00003	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00007	0.000035	0.022	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.00014	-0.00007	-0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.00094	-0.00047	-0.030	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00005	0.000025	0.002	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00097	-0.00048	-0.031	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00015	0.000075	0.005	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.00021	-0.0001	-0.007	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.00073	0.00036	0.023	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00095	-0.00047	-0.030	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00008	0.00004	0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00006	-0.00003	-0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00107	-0.00053	-0.034	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00015	-0.000075	-0.005	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00025	-0.00012	-0.008	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00014	0.00007	0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00002	-0.00001	-0.001	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00058	0.00029	0.019	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00002	0.00001	0.001	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00017	0.000085	0.005	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.0001	-0.00005	-0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00001	0.000005	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0	0	0.000	0.000	0.00%
TOTAL				0.434	100%

APPENDIX 44

ANOVA TABLE FOR THE RESPONSE COST; INCREASED ARRIVAL OF RAW MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.001188	0.001188	47.57	0.000*
Buffer capacity	1	0.381058	0.381058	15254.05	0.000*
Set up duration	1	0.037660	0.037660	1507.56	0.000*
Operator skills*Buffer capacity	1	0.010078	0.010078	403.42	0.000*
Operator skills*Set up duration	1	0.001401	0.001401	56.09	0.000*
Buffer capacity*Set up duration	1	0.001014	0.001014	40.58	0.000*
Operator skills*Buffer capacity* Set up duration	1	0.000666	0.000666	26.66	0.000*
Error	56	0.001399	0.000025		
Total	63	0.434464			

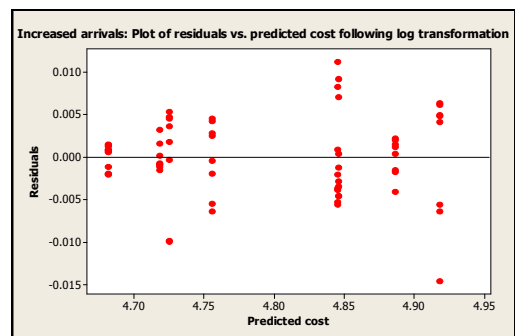
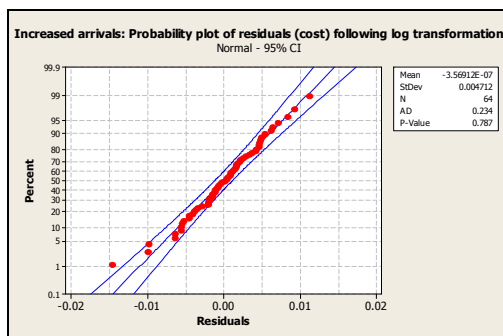
S = 0.00499808 R-Sq = 99.68% R-Sq(adj) = 99.64%

* Significant factors

APPENDIX 45

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO: RESIDUALS FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	4.6788	4.6809	-0.0020	f	4.7241	4.7243	-0.0003
a	4.7191	4.7175	0.0017	af	4.7532	4.7551	-0.0020
b	4.8530	4.8459	0.0071	bf	4.9125	4.9182	-0.0056
ab	4.8535	4.8452	0.0083	abf	4.8863	4.8859	0.0004
c	4.6814	4.6809	0.0006	cf	4.7289	4.7243	0.0045
ac	4.7165	4.7175	-0.0010	acf	4.7580	4.7551	0.0029
bc	4.8430	4.8459	-0.0028	bcf	4.9230	4.9182	0.0048
abc	4.8413	4.8452	-0.0039	abcf	4.8873	4.8859	0.0015
d	4.6789	4.6809	-0.0020	df	4.7261	4.7243	0.0018
ad	4.7168	4.7175	-0.0007	adf	4.7547	4.7551	-0.0005
bd	4.8446	4.8459	-0.0012	bdf	4.9246	4.9182	0.0064
abd	4.8432	4.8452	-0.0020	abdf	4.8843	4.8859	-0.0015
cd	4.6824	4.6809	0.0016	cdf	4.7279	4.7243	0.0036
acd	4.7160	4.7175	-0.0015	acdf	4.7594	4.7551	0.0043
bcd	4.8413	4.8459	-0.0046	bcdf	4.9244	4.9182	0.0062
abcd	4.8396	4.8452	-0.0056	abcdf	4.8881	4.8859	0.0022
e	4.6818	4.6809	0.0009	ef	4.7143	4.7243	-0.0100
ae	4.7207	4.7175	0.0033	aef	4.7487	4.7551	-0.0064
be	4.8551	4.8459	0.0092	bef	4.9036	4.9182	-0.0146
abe	4.8564	4.8452	0.0112	abef	4.8842	4.8859	-0.0017
ce	4.6817	4.6809	0.0008	cef	4.7291	4.7243	0.0047
ace	4.7167	4.7175	-0.0008	acef	4.7577	4.7551	0.0026
bce	4.8424	4.8459	-0.0035	bcef	4.9223	4.9182	0.0042
abce	4.8415	4.8452	-0.0037	abcef	4.8870	4.8859	0.0012
de	4.6797	4.6809	-0.0012	def	4.7145	4.7243	-0.0098
ade	4.7176	4.7175	0.0001	def	4.7497	4.7551	-0.0055
bde	4.8462	4.8459	0.0004	bdef	4.9118	4.9182	-0.0064
abde	4.8461	4.8452	0.0009	abdef	4.8818	4.8859	-0.0041
cde	4.6822	4.6809	0.0013	cdef	4.7297	4.7243	0.0054
acde	4.7163	4.7175	-0.0011	acdef	4.7597	4.7551	0.0046
bcde	4.8413	4.8459	-0.0046	bcdef	4.9231	4.9182	0.0050
abcde	4.8399	4.8452	-0.0053	abcdef	4.8879	4.8859	0.0020



APPENDIX 46

INCREASED ARRIVALS OF RAW-MATERIAL SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.05558			
Operators skills	-0.0818	-0.0409	-2.618	0.107	46.23%
Buffer capacity	0.01874	0.00937	0.600	0.006	2.43%
Number of vehicles	-0.00577	-0.00289	-0.185	0.001	0.23%
Vehicle speed	-0.0103	-0.00515	-0.330	0.002	0.73%
Loading capacity	0.00155	0.00077	0.050	0.000	0.02%
Set up duration	0.07642	0.03821	2.445	0.093	40.35%
Operators skills*Buffer capacity	-0.0187	-0.00935	-0.598	0.006	2.42%
Operators skills*Number of vehicles	-0.00884	-0.00442	-0.283	0.001	0.54%
Operators skills*Vehicle speed	-0.00353	-0.00176	-0.113	0.000	0.09%
Operators skills*Loading capacity	0.00212	0.00106	0.068	0.000	0.03%
Operators skills*Set up duration	-0.02547	-0.01274	-0.815	0.010	4.48%
Buffer capacity*Number of vehicles	-0.00198	-0.00099	-0.063	0.000	0.03%
Buffer capacity*Vehicle speed	0.00092	0.00046	0.029	0.000	0.01%
Buffer capacity*Loading capacity	-0.00055	-0.00028	-0.018	0.000	0.00%
Buffer capacity*Set up duration	0.00456	0.00228	0.146	0.000	0.14%
Number of vehicles*Vehicle speed	0.00533	0.00266	0.171	0.000	0.20%
Number of vehicles*Loading capacity	0.00028	0.00014	0.009	0.000	0.00%
Number of vehicles*Set up duration	0.01159	0.0058	0.371	0.002	0.93%
Vehicle speed*Loading capacity	-0.00117	-0.00059	-0.037	0.000	0.01%
Vehicle speed*Set up duration	0.00496	0.00248	0.159	0.000	0.17%
Loading capacity*Set up duration	-0.00385	-0.00193	-0.123	0.000	0.10%
Operators skills*Buffer capacity*Number of vehicles	0.00193	0.00096	0.062	0.000	0.03%
Operators skills*Buffer capacity*Vehicle speed	-0.00163	-0.00081	-0.052	0.000	0.02%
Operators skills*Buffer capacity*Loading capacity	0.00072	0.00036	0.023	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00559	-0.00279	-0.179	0.000	0.22%
Operators skills*Number of vehicles*Vehicle speed	0.00239	0.00119	0.076	0.000	0.04%
Operators skills*Number of vehicles*Loading capacity	-0.00297	-0.00149	-0.095	0.000	0.06%
Operators skills*Number of vehicles*Set up duration	-0.0021	-0.00105	-0.067	0.000	0.03%
Operators skills*Vehicle speed*Loading capacity	0.00041	0.00021	0.013	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00086	-0.00043	-0.028	0.000	0.01%
Operators skills*Loading capacity*Set up duration	0.00151	0.00076	0.048	0.000	0.02%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00059	-0.0003	-0.019	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00065	-0.00033	-0.021	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00172	0.00086	0.055	0.000	0.02%
Buffer capacity*Vehicle speed*Loading capacity	0.00025	0.00013	0.008	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00224	0.00112	0.072	0.000	0.03%
Buffer capacity*Loading capacity*Set up duration	0.00003	0.00002	0.001	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00158	0.00079	0.051	0.000	0.02%
Number of vehicles*Vehicle speed*Set up duration	-0.00271	-0.00136	-0.087	0.000	0.05%
Number of vehicles*Loading capacity*Set up duration	0.00488	0.00244	0.156	0.000	0.16%
Vehicle speed*Loading capacity*Set up duration	-0.00019	-0.0001	-0.006	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00135	0.00067	0.043	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.00053	0.00026	0.017	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.00069	-0.00034	-0.022	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.00011	-0.00005	-0.004	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00178	-0.00089	-0.057	0.000	0.02%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00021	0.00011	0.007	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.00081	-0.0004	-0.026	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.00096	0.00048	0.031	0.000	0.01%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00295	-0.00148	-0.094	0.000	0.06%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00011	0.00006	0.004	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00049	-0.00025	-0.016	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00172	-0.00086	-0.055	0.000	0.02%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00133	-0.00066	-0.043	0.000	0.01%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00042	-0.00021	-0.013	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00044	0.00022	0.014	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00027	0.00013	0.009	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00135	0.00067	0.043	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00105	0.00053	0.034	0.000	0.01%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00018	0.00009	0.006	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00024	-0.00012	-0.008	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00006	0.00003	0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00008	0.00004	0.003	0.000	0.00%
TOTAL				0.232	100%

APPENDIX 47

ANOVA TABLE FOR THE RESPONSE TIME; INCREASED ARRIVAL OF MATERIAL SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.107060	0.107060	2446.42	0.000*
Buffer capacity	1	0.005619	0.005619	128.41	0.000*
Number of vehicles	1	0.000533	0.000533	12.18	0.001*
Vehicle speed	1	0.001696	0.001696	38.75	0.000*
Set up duration	1	0.093452	0.093452	2135.48	0.000*
Operator skills*Buffer capacity	1	0.005592	0.005592	127.79	0.000*
Operator skills*Number of vehicles	1	0.001251	0.001251	28.59	0.000*
Operator skills*Set up duration	1	0.010382	0.010382	237.23	0.000*
Number of vehicles*Vehicle speed	1	0.000454	0.000454	10.37	0.002*
Number of vehicles*Set up duration	1	0.002151	0.002151	49.15	0.000*
Vehicle speed*Set up duration	1	0.000394	0.000394	9.00	0.004*
Buffer capacity*Set up duration	1	0.000333	0.000333	7.62	0.008
Operator skills*Buffer capacity* Set up duration	1	0.000500	0.000500	11.42	0.001*
Error	50	0.002188	0.000044		
Total	63	0.231605			

S = 0.00661527 R-Sq = 99.06% R-Sq(adj) = 98.81%

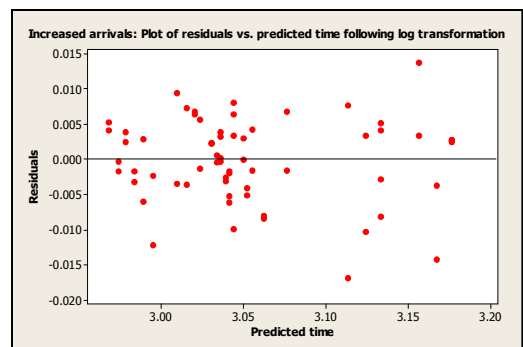
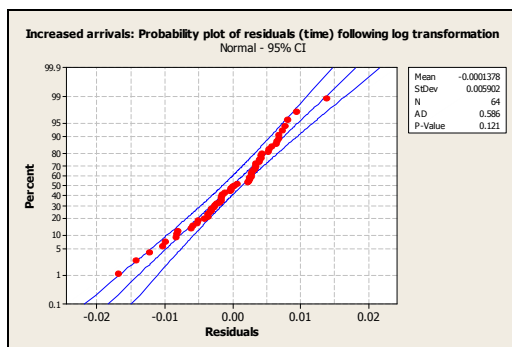
* Significant factors

APPENDIX 48

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}
(1)	3.0342	3.0442	-0.0100
a	3.0063	3.0098	-0.0035
b	3.0744	3.0760	-0.0017
ab	3.0117	3.0154	-0.0037
c	3.0326	3.0303	0.0023
ac	2.9806	2.9783	0.0024
bc	3.0540	3.0622	-0.0081
abc	2.9806	2.9839	-0.0033
d	3.0223	3.0236	-0.0013
ad	2.9832	2.9892	-0.0060
bd	3.0538	3.0554	-0.0016
abd	2.9826	2.9948	-0.0123
cd	3.0268	3.0204	0.0064
acd	2.9724	2.9683	0.0040
bcd	3.0470	3.0522	-0.0052
abcd	2.9722	2.9739	-0.0017
e	3.0505	3.0442	0.0064
ae	3.0192	3.0098	0.0094
be	3.0827	3.0760	0.0067
abe	3.0226	3.0154	0.0072
ce	3.0325	3.0303	0.0022
ace	2.9821	2.9783	0.0038
bce	3.0537	3.0622	-0.0085
abce	2.9822	2.9839	-0.0017
de	3.0292	3.0236	0.0056
ade	2.9921	2.9892	0.0028
bde	3.0596	3.0554	0.0042
abde	2.9924	2.9948	-0.0024
cde	3.0271	3.0204	0.0067
acde	2.9736	2.9683	0.0052
bcde	3.0480	3.0522	-0.0042
abcde	2.9736	2.9739	-0.0004

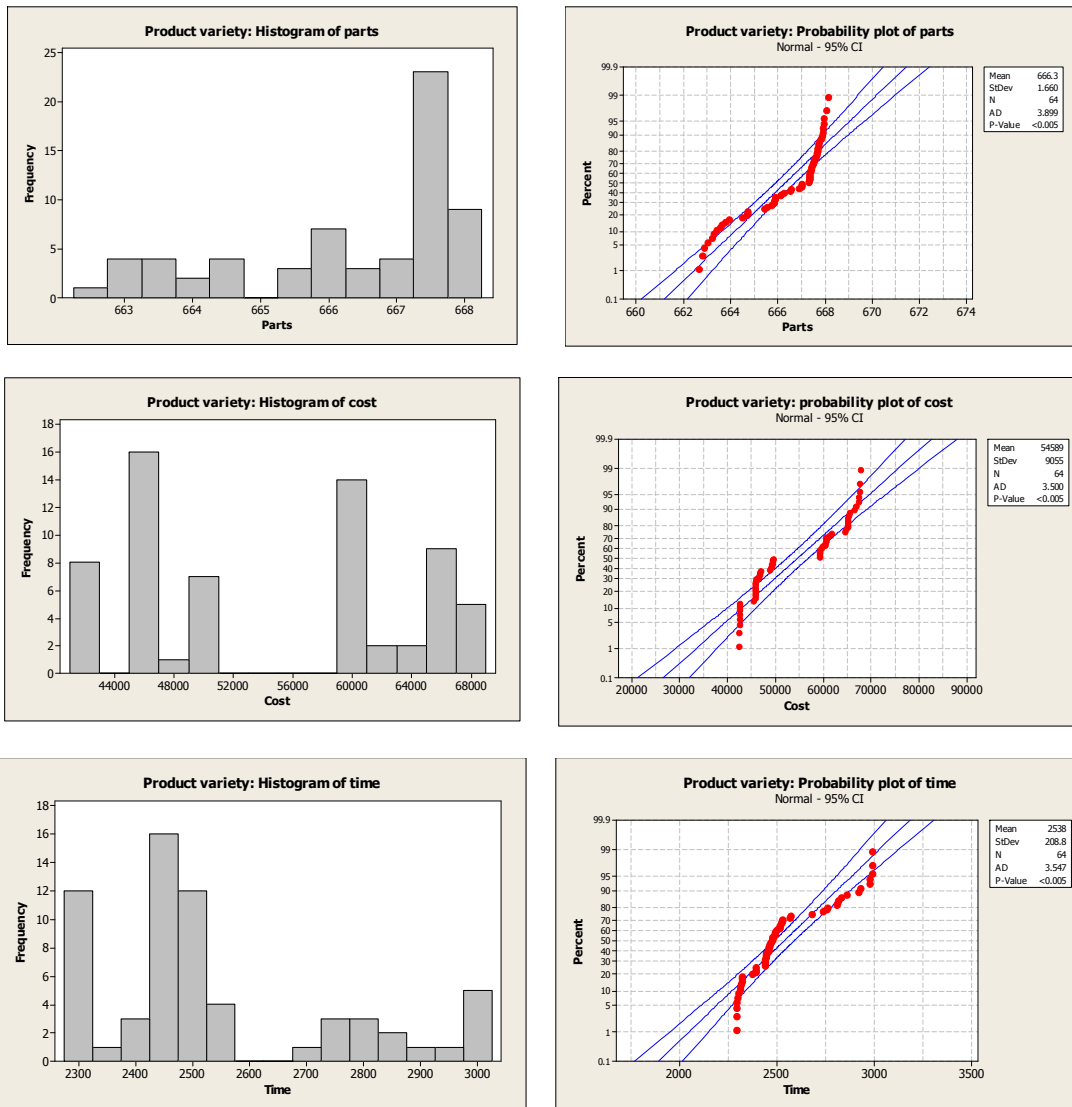
Run	y	\hat{y}	e=y- \hat{y}
f	3.1272	3.1239	0.0033
af	3.0497	3.0498	-0.0001
bf	3.1632	3.1669	-0.0038
abf	3.0475	3.0442	0.0033
cf	3.1304	3.1333	-0.0028
acf	3.0394	3.0414	-0.0020
bcf	3.1789	3.1763	0.0026
abcf	3.0391	3.0359	0.0032
df	3.1209	3.1133	0.0076
adf	3.0364	3.0391	-0.0027
bdf	3.1700	3.1563	0.0137
abdf	3.0330	3.0336	-0.0005
cdf	3.1250	3.1332	-0.0083
acdf	3.0352	3.0414	-0.0062
bcdf	3.1786	3.1763	0.0024
abcdf	3.0355	3.0359	-0.0003
ef	3.1136	3.1239	-0.0104
aef	3.0528	3.0498	0.0030
bef	3.1527	3.1669	-0.0143
abef	3.0523	3.0442	0.0081
cef	3.1384	3.1333	0.0051
acef	3.0397	3.0414	-0.0017
bcef	3.1789	3.1763	0.0026
abcef	3.0397	3.0359	0.0038
def	3.0963	3.1133	-0.0170
adef	3.0359	3.0391	-0.0032
bdef	3.1596	3.1563	0.0033
abdef	3.0341	3.0336	0.0006
cdef	3.1373	3.1332	0.0041
acdef	3.0361	3.0414	-0.0053
bcdef	3.1789	3.1763	0.0027
abcdef	3.0360	3.0359	0.0002



APPENDIX 49

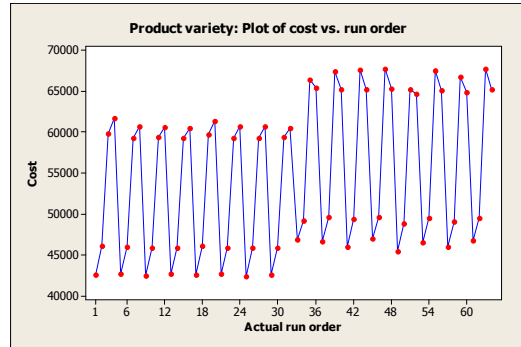
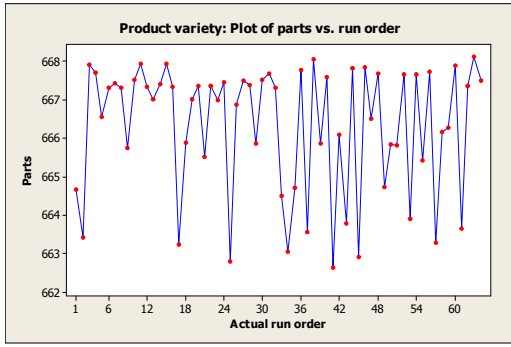
INCREASED PRODUCT VARIETY SCENARIO: EXPLORATORY DATA ANALYSIS

The histograms and probability plots show that none of the three responses display a normally distributed behaviour; therefore data transformation may be required for the three responses in this scenario.

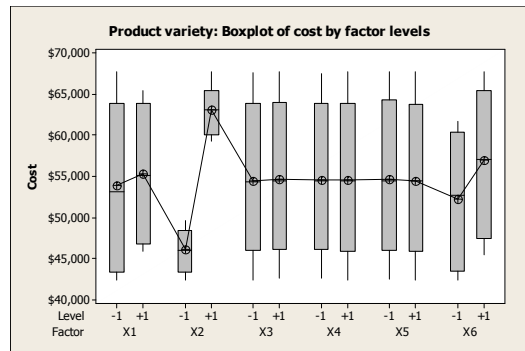
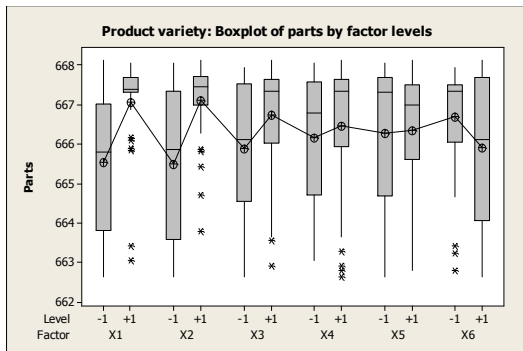


The time series plots do not show any relationship between the sequence of the experiments and the level of the three responses.

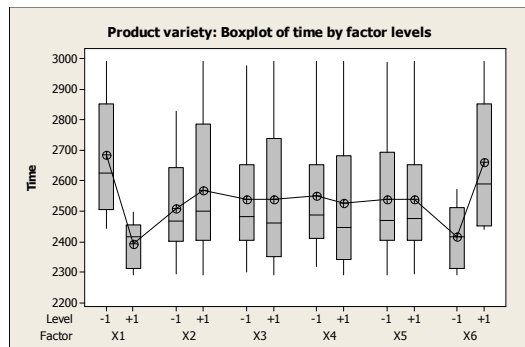
APPENDIX 49 (continued)



The box plots show that factors X1 (skill level of operators) and X2 (buffer capacity) may be of significance in terms of throughput. Factor X2 produces a significant change in the average cost. And, in terms of average time in the system, factors X1 and X6 (set up duration) may be the significant factors.



- Factors**
- X1:** Skill level of operators
 - X2:** Buffer capacity
 - X3:** Number of AVGs
 - X4:** Speed of AVGs
 - X5:** Loading capacity of AVGs
 - X6:** Duration of set-ups



APPENDIX 50

INCREASED PRODUCT VARIETY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		666.354			
Operators skills	1.619	0.81	51.808	41.939	26.36%
Buffer capacity	1.526	0.763	48.832	37.259	23.42%
Number of vehicles	0.749	0.375	23.968	8.976	5.64%
Vehicle speed	0.207	0.103	6.624	0.686	0.43%
Loading capacity	-0.039	-0.019	-1.248	0.024	0.02%
Set up duration	-0.773	-0.387	-24.736	9.560	6.01%
Operators skills*Buffer capacity	-0.749	-0.374	-23.968	8.976	5.64%
Operators skills*Number of vehicles	-0.023	-0.012	-0.736	0.008	0.01%
Operators skills*Vehicle speed	0.095	0.047	3.040	0.144	0.09%
Operators skills*Loading capacity	0.076	0.038	2.432	0.092	0.06%
Operators skills*Set up duration	0.864	0.432	27.648	11.944	7.51%
Buffer capacity*Number of vehicles	-0.499	-0.25	-15.968	3.984	2.50%
Buffer capacity*Vehicle speed	0.061	0.03	1.952	0.060	0.04%
Buffer capacity*Loading capacity	0.194	0.097	6.208	0.602	0.38%
Buffer capacity*Set up duration	0.056	0.028	1.792	0.050	0.03%
Number of vehicles*Vehicle speed	0.038	0.019	1.216	0.023	0.01%
Number of vehicles*Loading capacity	-0.04	-0.02	-1.280	0.026	0.02%
Number of vehicles*Set up duration	-0.022	-0.011	-0.704	0.008	0.00%
Vehicle speed*Loading capacity	0.018	0.009	0.576	0.005	0.00%
Vehicle speed*Set up duration	-0.208	-0.104	-6.656	0.692	0.44%
Loading capacity*Set up duration	0.474	0.237	15.168	3.595	2.26%
Operators skills*Buffer capacity*Number of vehicles	-0.351	-0.176	-11.232	1.971	1.24%
Operators skills*Buffer capacity*Vehicle speed	-0.398	-0.199	-12.736	2.534	1.59%
Operators skills*Buffer capacity*Loading capacity	-0.264	-0.132	-8.448	1.115	0.70%
Operators skills*Buffer capacity*Set up duration	0.16	0.08	5.120	0.410	0.26%
Operators skills*Number of vehicles*Vehicle speed	-0.401	-0.201	-12.832	2.573	1.62%
Operators skills*Number of vehicles*Loading capacity	-0.081	-0.041	-2.592	0.105	0.07%
Operators skills*Number of vehicles*Set up duration	0.231	0.115	7.392	0.854	0.54%
Operators skills*Vehicle speed*Loading capacity	-0.187	-0.094	-5.984	0.560	0.35%
Operators skills*Vehicle speed*Set up duration	0.075	0.038	2.400	0.090	0.06%
Operators skills*Loading capacity*Set up duration	-0.485	-0.243	-15.520	3.764	2.37%
Buffer capacity*Number of vehicles*Vehicle speed	0.233	0.116	7.456	0.869	0.55%
Buffer capacity*Number of vehicles*Loading capacity	-0.046	-0.023	-1.472	0.034	0.02%
Buffer capacity*Number of vehicles*Set up duration	0.358	0.179	11.456	2.051	1.29%
Buffer capacity*Vehicle speed*Loading capacity	0.243	0.122	7.776	0.945	0.59%
Buffer capacity*Vehicle speed*Set up duration	0.317	0.158	10.144	1.608	1.01%
Buffer capacity*Loading capacity*Set up duration	-0.043	-0.022	-1.376	0.030	0.02%
Number of vehicles*Vehicle speed*Loading capacity	0.107	0.053	3.424	0.183	0.12%
Number of vehicles*Vehicle speed*Set up duration	0.187	0.094	5.984	0.560	0.35%
Number of vehicles*Loading capacity*Set up duration	-0.229	-0.114	-7.328	0.839	0.53%
Vehicle speed*Loading capacity*Set up duration	0.165	0.082	5.280	0.436	0.27%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.108	0.054	3.456	0.187	0.12%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.218	0.109	6.976	0.760	0.48%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.602	-0.301	-19.264	5.798	3.64%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.062	-0.031	-1.984	0.062	0.04%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.109	-0.055	-3.488	0.190	0.12%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.065	0.033	2.080	0.068	0.04%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	-0.001	-0.001	-0.032	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.15	-0.075	-4.800	0.360	0.23%
Operators skills*Number of vehicles*Loading capacity*Set up duration	0.087	0.044	2.784	0.121	0.08%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.158	-0.079	-5.056	0.399	0.25%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.149	-0.075	-4.768	0.355	0.22%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.032	-0.016	-1.024	0.016	0.01%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.01	0.005	0.320	0.002	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.012	-0.006	-0.384	0.002	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.04	-0.02	-1.280	0.026	0.02%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.088	-0.044	-2.816	0.124	0.08%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.089	-0.044	-2.848	0.127	0.08%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.078	0.039	2.496	0.097	0.06%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.035	-0.018	-1.120	0.020	0.01%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.008	-0.004	-0.256	0.001	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.102	0.051	3.264	0.166	0.10%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.046	-0.023	-1.472	0.034	0.02%
TOTAL				159.097	100%

APPENDIX 51

ANOVA TABLE FOR THE RESPONSE NUMBER OF PARTS; INCREASED PRODUCT VARIETY SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	41.9398	41.9398	98.59	0.000*
Buffer capacity	1	37.2434	37.2434	87.55	0.000*
Number of vehicles	1	8.9803	8.9803	21.11	0.000*
Vehicle speed	1	0.6831	0.6831	1.61	0.213
Loading capacity	1	0.0241	0.0241	0.06	0.813
Set up duration	1	9.5636	9.5636	22.48	0.000*
Operator skills*Buffer capacity	1	8.9670	8.9670	21.08	0.000*
Operator skills*Number of vehicles	1	0.0088	0.0088	0.02	0.886
Operator skills*Vehicle speed	1	0.1441	0.1441	0.34	0.564
Operator skills*Loading capacity	1	0.0923	0.0923	0.22	0.644
Operator skills*Set up duration	1	11.9461	11.9461	28.08	0.000*
Buffer capacity*Number of vehicles	1	3.9882	3.9882	9.38	0.004*
Buffer capacity*Vehicle speed	1	0.0595	0.0595	0.14	0.710
Buffer capacity*Set up duration	1	0.0500	0.0500	0.12	0.733
Number of vehicles*Vehicle speed	1	0.0232	0.0232	0.05	0.817
Number of vehicles*Set up duration	1	0.0076	0.0076	0.02	0.894
Vehicle speed*Set up duration	1	0.6952	0.6952	1.63	0.209
Loading capacity*Set up duration	1	3.6001	3.6001	8.46	0.006*
Operator skills*Buffer capacity* Number of vehicles	1	1.9748	1.9748	4.64	0.037*
Operator skills*Buffer capacity* Vehicle speed	1	2.5394	2.5394	5.97	0.019*
Operator skills*Number of vehicles* Vehicle speed	1	2.5740	2.5740	6.05	0.018*
Operator skills*Loading capacity* Set up duration	1	3.7693	3.7693	8.86	0.005*
Buffer capacity*Number of vehicles* Set up duration	1	2.0502	2.0502	4.82	0.034*
Buffer capacity*Vehicle speed* Set up duration	1	1.6033	1.6033	3.77	0.059*
Error	39	16.5902	0.4254		
Total	63	159.1176			

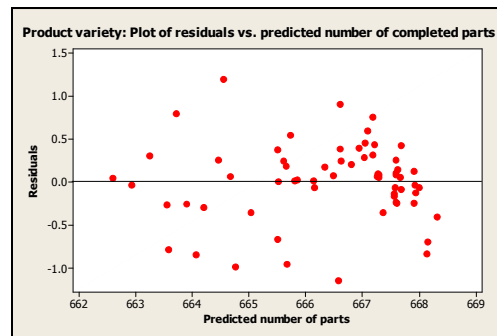
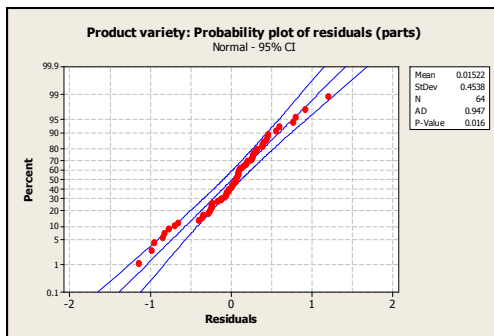
S = 0.652218 R-Sq = 89.57% R-Sq(adj) = 83.16%

* Significant factors

APPENDIX 52

INCREASED ARRIVALS OF RAW MATERIAL SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	665	665.019	-0.35	f	665	663.697	0.80
a	665	665.487	-0.66	af	665	665.661	-0.95
b	668	668.319	-0.40	bf	665	664.445	0.27
ab	668	667.587	0.11	abf	668	667.617	0.15
c	667	666.475	0.09	cf	664	663.233	0.31
ac	667	667.247	0.08	acf	668	667.909	0.14
bc	667	667.559	-0.13	bcf	666	665.605	0.25
abc	667	668.131	-0.83	abcf	668	667.673	-0.08
d	666	664.535	1.21	df	663	662.581	0.06
ad	668	666.603	0.92	adf	666	666.145	-0.06
bd	668	667.999	-0.06	bdf	664	664.757	-0.98
abd	667	667.275	0.06	abdf	668	667.937	-0.12
cd	667	666.795	0.21	cdf	663	662.921	-0.03
acd	667	667.559	-0.16	acdf	668	667.589	0.27
bcd	668	667.171	0.77	bcdf	667	666.323	0.19
abcd	667	666.939	0.41	abcdf	668	667.587	0.09
e	663	664.059	-0.84	ef	665	664.657	0.07
ae	666	665.499	0.38	aef	666	665.649	0.19
be	667	667.359	-0.35	bef	666	665.803	0.02
abe	667	667.599	-0.24	abef	668	667.207	0.45
ce	666	665.515	0.01	cef	664	664.193	-0.28
ace	667	667.259	0.10	acef	668	667.897	-0.24
bce	667	666.599	0.39	bcef	665	666.565	-1.14
abce	667	668.143	-0.69	abcef	668	667.661	0.06
de	663	663.575	-0.78	def	663	663.541	-0.26
ade	667	666.615	0.26	adef	666	666.133	0.02
bde	668	667.039	0.47	bdef	666	665.717	0.55
abde	667	667.287	0.09	abdef	668	667.925	-0.03
cde	666	665.835	0.03	cdef	664	663.881	-0.25
acde	668	667.571	-0.05	acdef	667	667.577	-0.23
bcde	668	667.083	0.60	bcdef	668	667.681	0.44
abcde	667	667.027	0.29	abcdef	668	667.177	0.33



APPENDIX 53

INCREASED PRODUCT VARIETY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.73118			
Operators skills	0.01443	0.00722	0.462	0.003	1.00%
Buffer capacity	0.13698	0.06849	4.383	0.300	90.45%
Number of vehicles	0.00166	0.00083	0.053	0.000	0.01%
Vehicle speed	-0.00011	-0.00006	-0.004	0.000	0.00%
Loading capacity	-0.00156	-0.00078	-0.050	0.000	0.01%
Set up duration	0.03756	0.01878	1.202	0.023	6.80%
Operators skills*Buffer capacity	-0.01559	-0.00779	-0.499	0.004	1.17%
Operators skills*Number of vehicles	-0.00163	-0.00082	-0.052	0.000	0.01%
Operators skills*Vehicle speed	-0.00091	-0.00046	-0.029	0.000	0.00%
Operators skills*Loading capacity	0.0003	0.00015	0.010	0.000	0.00%
Operators skills*Set up duration	-0.00073	-0.00365	-0.234	0.001	0.26%
Buffer capacity*Number of vehicles	-0.00097	-0.00048	-0.031	0.000	0.00%
Buffer capacity*Vehicle speed	0.00013	0.00006	0.004	0.000	0.00%
Buffer capacity*Loading capacity	0.00006	0.00003	0.002	0.000	0.00%
Buffer capacity*Set up duration	0.00343	0.00171	0.110	0.000	0.06%
Number of vehicles*Vehicle speed	0.00054	0.00027	0.017	0.000	0.00%
Number of vehicles*Loading capacity	0.00124	0.00062	0.040	0.000	0.01%
Number of vehicles*Set up duration	0.00286	0.00143	0.092	0.000	0.04%
Vehicle speed*Loading capacity	0.00072	0.00036	0.023	0.000	0.00%
Vehicle speed*Set up duration	0.00191	0.00095	0.061	0.000	0.02%
Loading capacity*Set up duration	-0.00125	-0.00062	-0.040	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles	-0.00027	-0.00013	-0.009	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00009	-0.000045	-0.029	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.00014	-0.00007	-0.004	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00421	-0.0021	-0.135	0.000	0.09%
Operators skills*Number of vehicles*Vehicle speed	0.0003	0.00015	0.010	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	-0.00045	-0.00022	-0.014	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00054	-0.00027	-0.017	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	-0.00022	-0.00011	-0.007	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00024	-0.00012	-0.008	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00036	0.00018	0.012	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00028	-0.00014	-0.009	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	0.00027	0.00014	0.009	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00043	0.00022	0.014	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00014	-0.00007	-0.004	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00095	0.00048	0.030	0.000	0.00%
Buffer capacity*Loading capacity*Set up duration	0.00011	0.00006	0.004	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	-0.00008	-0.00004	-0.026	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00087	-0.00044	-0.028	0.000	0.00%
Number of vehicles*Loading capacity*Set up duration	0.00097	0.00049	0.031	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	0.00048	0.00024	0.015	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00009	0.000045	0.029	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.00008	-0.00004	-0.003	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	-0.00051	-0.00026	-0.016	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00038	0.00019	0.012	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00052	-0.00026	-0.017	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.00006	-0.00003	-0.002	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.0003	0.00015	0.010	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.00002	0.00001	0.001	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00038	-0.00019	-0.012	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00037	-0.00018	-0.012	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.0002	0.0001	0.006	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00091	-0.00046	-0.029	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00008	0.00004	0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00035	-0.00017	-0.011	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00075	-0.00038	-0.024	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.0005	-0.00025	-0.016	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00069	0.00034	0.022	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00004	-0.00002	-0.001	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00036	0.00018	0.012	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00043	0.00022	0.014	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00035	0.00017	0.011	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00033	-0.00016	-0.011	0.000	0.00%
TOTAL				0.332	100%

APPENDIX 54

ANOVA TABLE FOR THE RESPONSE COST; INCREASED PRODUCT VARIETY SCENARIO

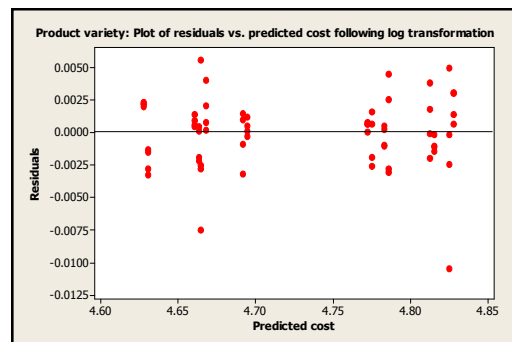
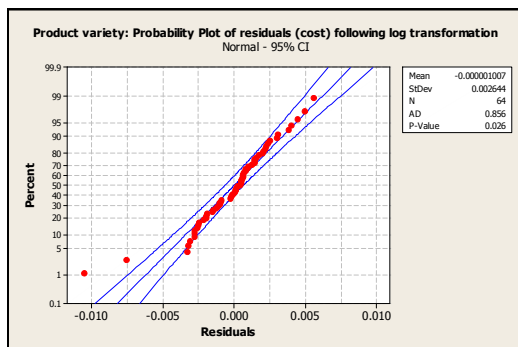
Source	DF	SS	MS	F	P
Operator skills	1	0.003333	0.003333	454.01	0.000*
Buffer capacity	1	0.300225	0.300225	40889.79	0.000*
Number of vehicles	1	0.000044	0.000044	5.98	0.018
Set up duration	1	0.022568	0.022568	3073.68	0.000*
Operator skills*Buffer capacity	1	0.003886	0.003886	529.32	0.000*
Operator skills*Set up duration	1	0.000853	0.000853	116.11	0.000*
Buffer capacity*Set up duration	1	0.000188	0.000188	25.60	0.000*
Number of vehicles*Set up duration	1	0.000130	0.000130	17.77	0.000*
Operator skills*Buffer capacity*	1	0.000284	0.000284	38.62	0.000*
Set up duration					
Error	54	0.000396	0.000007		
Total	63	0.331907			
S = 0.00270967 R-Sq = 99.88% R-Sq(adj) = 99.86%					

* Significant factors

APPENDIX 55

INCREASED PRODUCT VARIETY SCENARIO: RESIDUALS FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	4.6292	4.6305	-0.0013	f	4.6704	4.6649	0.0056
a	4.6641	4.6636	0.0004	af	4.6928	4.6918	0.0010
b	4.7770	4.7754	0.0016	bf	4.8226	4.8251	-0.0024
ab	4.7903	4.7858	0.0045	abf	4.8162	4.8124	0.0038
c	4.6300	4.6276	0.0024	cf	4.6685	4.6677	0.0008
ac	4.6622	4.6608	0.0014	acf	4.6952	4.6947	0.0005
bc	4.7733	4.7726	0.0007	bcf	4.8286	4.8279	0.0007
abc	4.7834	4.7829	0.0005	abcf	4.8142	4.8153	-0.0011
d	4.6277	4.6305	-0.0028	df	4.6621	4.6649	-0.0028
ad	4.6617	4.6636	-0.0019	adf	4.6933	4.6918	0.0015
bd	4.7735	4.7754	-0.0019	bdf	4.8300	4.8251	0.0050
abd	4.7827	4.7858	-0.0031	abdf	4.8142	4.8124	0.0018
cd	4.6298	4.6276	0.0022	cdf	4.6718	4.6677	0.0040
acd	4.6612	4.6608	0.0005	acdf	4.6959	4.6947	0.0012
bcd	4.7726	4.7726	0.0001	bcdf	4.8309	4.8279	0.0030
abcd	4.7820	4.7829	-0.0010	abcdf	4.8151	4.8153	-0.0002
e	4.6290	4.6305	-0.0015	ef	4.6574	4.6649	-0.0075
ae	4.6638	4.6636	0.0001	aef	4.6886	4.6918	-0.0032
be	4.7761	4.7754	0.0006	bef	4.8146	4.8251	-0.0105
abe	4.7883	4.7858	0.0025	abef	4.8105	4.8124	-0.0019
ce	4.6299	4.6276	0.0022	cef	4.6679	4.6677	0.0002
ace	4.6617	4.6608	0.0009	acef	4.6944	4.6947	-0.0003
bce	4.7732	4.7726	0.0006	bcef	4.8293	4.8279	0.0014
abce	4.7832	4.7829	0.0002	abcef	4.8139	4.8153	-0.0014
de	4.6272	4.6305	-0.0033	def	4.6624	4.6649	-0.0025
ade	4.6615	4.6636	-0.0022	def	4.6909	4.6918	-0.0009
bde	4.7729	4.7754	-0.0026	bdef	4.8249	4.8251	-0.0001
abde	4.7830	4.7858	-0.0028	abdef	4.8124	4.8124	-0.0001
cde	4.6296	4.6276	0.0020	cdef	4.6698	4.6677	0.0021
acde	4.6613	4.6608	0.0006	acdef	4.6948	4.6947	0.0001
bcde	4.7734	4.7726	0.0008	bcdef	4.8310	4.8279	0.0031
abcde	4.7819	4.7829	-0.0010	abcdef	4.8143	4.8153	-0.0010



APPENDIX 56

INCREASED PRODUCT VARIETY SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.40302			
Operators skills	-0.04905	-0.02452	-1.570	0.038	51.03%
Buffer capacity	0.00916	0.00458	0.293	0.001	1.78%
Number of vehicles	-0.0001	-0.00005	-0.003	0.000	0.00%
Vehicle speed	-0.00429	-0.00215	-0.137	0.000	0.39%
Loading capacity	0.00021	0.0001	0.007	0.000	0.00%
Set up duration	0.0411	0.02055	1.315	0.027	35.83%
Operators skills*Buffer capacity	-0.00907	-0.00453	-0.290	0.001	1.74%
Operators skills*Number of vehicles	-0.00475	-0.00238	-0.152	0.000	0.48%
Operators skills*Vehicle speed	-0.00346	-0.00173	-0.111	0.000	0.25%
Operators skills*Loading capacity	0.00007	0.00003	0.002	0.000	0.00%
Operators skills*Set up duration	-0.01704	-0.00852	-0.545	0.005	6.16%
Buffer capacity*Number of vehicles	-0.00087	-0.00043	-0.028	0.000	0.02%
Buffer capacity*Vehicle speed	-0.00002	-0.00001	-0.001	0.000	0.00%
Buffer capacity*Loading capacity	-0.00083	-0.00041	-0.027	0.000	0.01%
Buffer capacity*Set up duration	0.00432	0.00216	0.138	0.000	0.40%
Number of vehicles*Vehicle speed	0.00188	0.00094	0.060	0.000	0.07%
Number of vehicles*Loading capacity	0.00067	0.00034	0.021	0.000	0.01%
Number of vehicles*Set up duration	0.00463	0.00232	0.148	0.000	0.45%
Vehicle speed*Loading capacity	0.00049	0.00024	0.016	0.000	0.01%
Vehicle speed*Set up duration	0.00361	0.0018	0.116	0.000	0.28%
Loading capacity*Set up duration	-0.00166	-0.00083	-0.053	0.000	0.06%
Operators skills*Buffer capacity*Number of vehicles	0.00069	0.00034	0.022	0.000	0.01%
Operators skills*Buffer capacity*Vehicle speed	-0.00033	-0.00017	-0.011	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	0.00047	0.00024	0.015	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00469	-0.00234	-0.150	0.000	0.47%
Operators skills*Number of vehicles*Vehicle speed	0.00184	0.00092	0.059	0.000	0.07%
Operators skills*Number of vehicles*Loading capacity	-0.00068	-0.00034	-0.022	0.000	0.01%
Operators skills*Number of vehicles*Set up duration	-0.00224	-0.00112	-0.072	0.000	0.11%
Operators skills*Vehicle speed*Loading capacity	-0.00035	-0.00017	-0.011	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	-0.00138	-0.00069	-0.044	0.000	0.04%
Operators skills*Loading capacity*Set up duration	0.00089	0.00044	0.028	0.000	0.02%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00006	-0.00003	-0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	0.00086	0.00043	0.028	0.000	0.02%
Buffer capacity*Number of vehicles*Set up duration	0.00009	0.00005	0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00014	-0.00007	-0.004	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00045	0.00023	0.014	0.000	0.00%
Buffer capacity*Loading capacity*Set up duration	0.00023	0.00011	0.007	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	-0.0005	-0.00025	-0.016	0.000	0.01%
Number of vehicles*Vehicle speed*Set up duration	-0.00201	-0.00101	-0.064	0.000	0.09%
Number of vehicles*Loading capacity*Set up duration	0.00154	0.00077	0.049	0.000	0.05%
Vehicle speed*Loading capacity*Set up duration	0.00066	0.00033	0.021	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00047	0.00023	0.015	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.00047	-0.00023	-0.015	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.00024	0.00012	0.008	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00062	0.00031	0.020	0.000	0.01%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00016	-0.00008	-0.005	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.00011	-0.00005	-0.004	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00037	0.00018	0.012	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.00081	0.0004	0.026	0.000	0.01%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00077	-0.00038	-0.025	0.000	0.01%
Operators skills*Vehicle speed*Loading capacity*Set up duration	-0.00059	-0.00029	-0.019	0.000	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00001	0	0.000	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00056	-0.00028	-0.018	0.000	0.01%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00019	-0.00009	-0.006	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00073	-0.00036	-0.023	0.000	0.01%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00072	-0.00036	-0.023	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00066	-0.00033	-0.021	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00036	0.00018	0.012	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.00008	0.00004	0.003	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00067	0.00034	0.021	0.000	0.01%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00062	0.00031	0.020	0.000	0.01%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00033	0.00017	0.011	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00038	-0.00019	-0.012	0.000	0.00%
TOTAL				0.075	100%

APPENDIX 57

**ANOVA TABLE FOR THE RESPONSE TIME; INCREASED PRODUCT VARIETY
SCENARIO**

Source	DF	SS	MS	F	P
Operator skills	1	0.0384908	0.0384908	2628.80	0.000*
Buffer capacity	1	0.0013422	0.0013422	91.67	0.000*
Number of vehicles	1	0.0000002	0.0000002	0.01	0.918
Vehicle speed	1	0.0002946	0.0002946	20.12	0.000*
Set up duration	1	0.0270225	0.0270225	1845.55	0.000*
Operator skills*Buffer capacity	1	0.0013150	0.0013150	89.81	0.000*
Operator skills*Number of vehicles	1	0.0003612	0.0003612	24.67	0.000*
Operator skills*Set up duration	1	0.0046484	0.0046484	317.47	0.000*
Buffer capacity*Set up duration	1	0.0002983	0.0002983	20.37	0.000*
Number of vehicles*Set up duration	1	0.0003432	0.0003432	23.44	0.000*
Vehicle speed*Set up duration	1	0.0002084	0.0002084	14.24	0.000*
Operator skills*Buffer capacity* Set up duration	1	0.0003513	0.0003513	24.00	0.000*
Error	51	0.0007467	0.0000146		
Total	63	0.0754229			

S = 0.00382648 R-Sq = 99.01% R-Sq(adj) = 98.78%

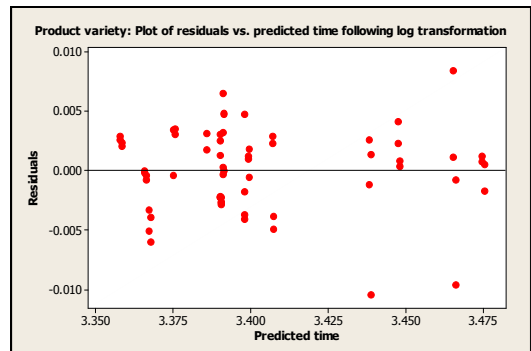
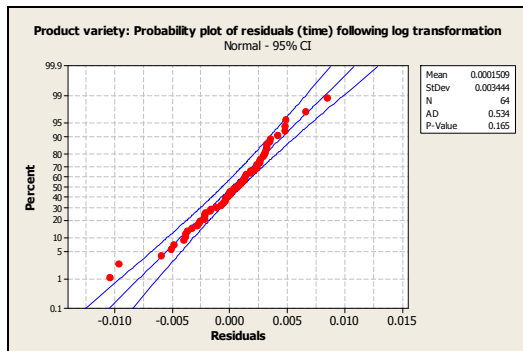
* Significant factors

APPENDIX 58

INCREASED PRODUCT VARIETY SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}
(1)	3.3941	3.3978	-0.0037
a	3.3745	3.3749	-0.0004
b	3.4093	3.4070	0.0023
ab	3.3789	3.3754	0.0035
c	3.3938	3.3979	-0.0040
ac	3.3653	3.3655	-0.0002
bc	3.4022	3.4071	-0.0049
abc	3.3652	3.3660	-0.0007
d	3.3876	3.3899	-0.0022
ad	3.3619	3.3670	-0.0051
bd	3.4001	3.3991	0.0010
abd	3.3615	3.3675	-0.0060
cd	3.3913	3.3900	0.0013
acd	3.3602	3.3576	0.0026
bcd	3.3987	3.3992	-0.0005
abcd	3.3602	3.3581	0.0021
e	3.4025	3.3978	0.0047
ae	3.3783	3.3749	0.0035
be	3.4099	3.4070	0.0029
abe	3.3785	3.3754	0.0031
ce	3.3961	3.3979	-0.0017
ace	3.3655	3.3655	0.0000
bce	3.4032	3.4071	-0.0039
abce	3.3655	3.3660	-0.0004
de	3.3929	3.3899	0.0031
ade	3.3637	3.3670	-0.0033
bde	3.4003	3.3991	0.0013
abde	3.3636	3.3675	-0.0039
cde	3.3925	3.3900	0.0026
acde	3.3605	3.3576	0.0029
bcde	3.4010	3.3992	0.0018
abcde	3.3604	3.3581	0.0024

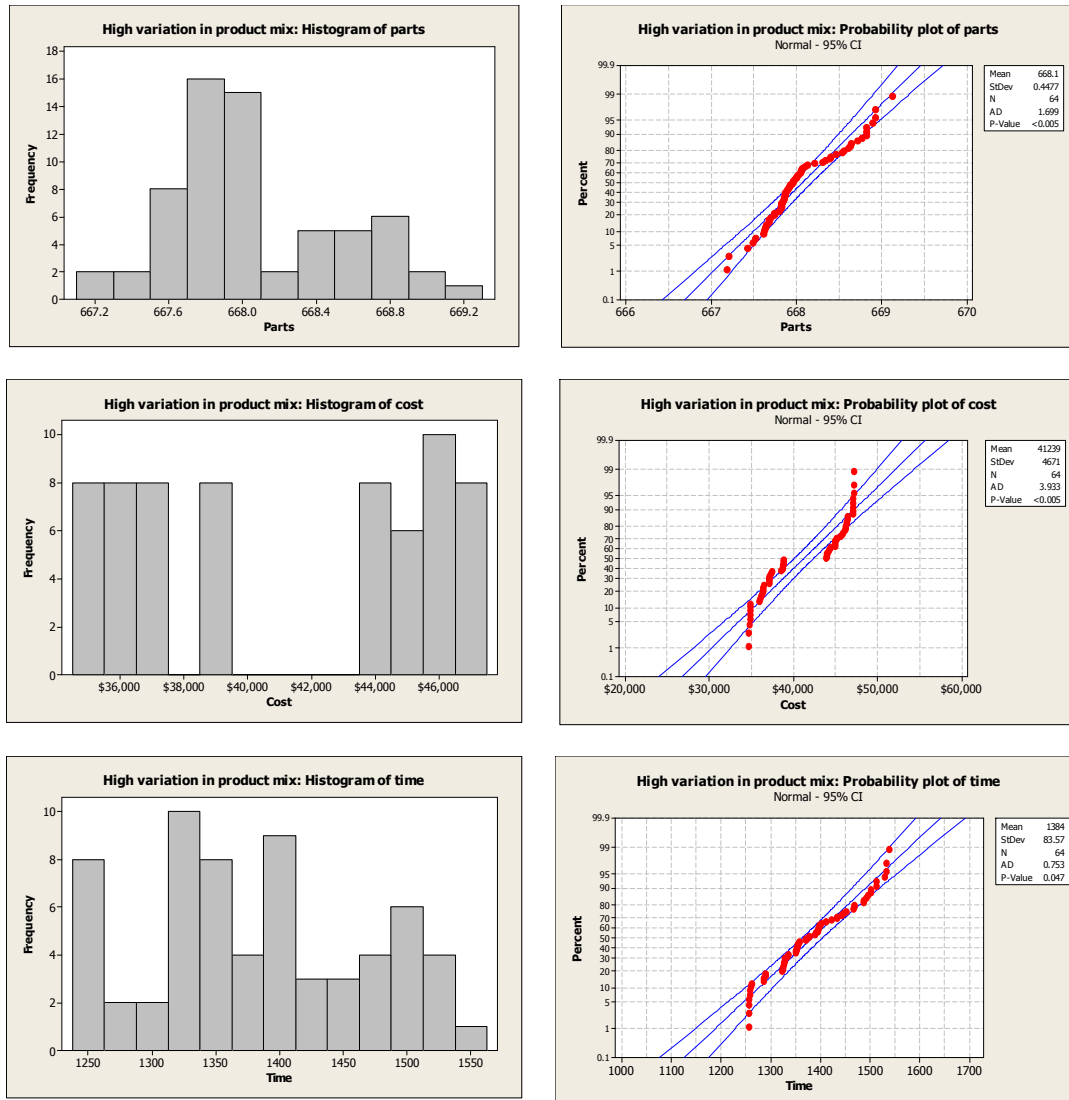
Run	y	\hat{y}	e=y- \hat{y}
f	3.4400	3.4387	0.0014
af	3.3959	3.3911	0.0048
bf	3.4651	3.4659	-0.0008
abf	3.3974	3.3908	0.0065
cf	3.4484	3.4481	0.0004
acf	3.3909	3.3910	0.0000
bcf	3.4736	3.4753	-0.0017
abcf	3.3904	3.3907	-0.0003
df	3.4368	3.4380	-0.0012
adf	3.3888	3.3856	0.0032
bdf	3.4736	3.4652	0.0085
abdf	3.3875	3.3901	-0.0026
cdf	3.4496	3.4474	0.0023
acdf	3.3875	3.3903	-0.0027
bcdf	3.4753	3.4746	0.0008
abcdf	3.3878	3.3900	-0.0022
ef	3.4282	3.4387	-0.0105
aef	3.3958	3.3911	0.0047
bef	3.4562	3.4659	-0.0096
abef	3.3940	3.3908	0.0032
cef	3.4489	3.4481	0.0009
acef	3.3909	3.3910	0.0000
bcef	3.4758	3.4753	0.0006
abcef	3.3910	3.3907	0.0003
def	3.4406	3.4380	0.0026
adef	3.3874	3.3856	0.0018
bdef	3.4663	3.4652	0.0012
abdef	3.3873	3.3901	-0.0028
cdef	3.4515	3.4474	0.0041
acdef	3.3880	3.3903	-0.0022
bcdef	3.4758	3.4746	0.0012
abcdef	3.3878	3.3900	-0.0022



APPENDIX 59

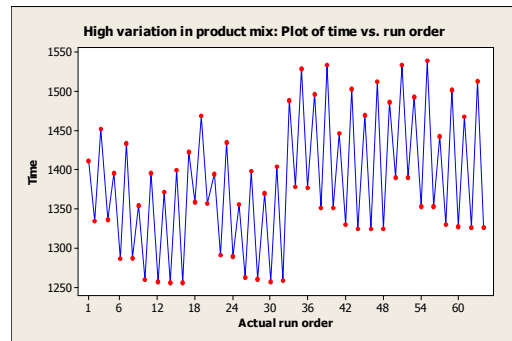
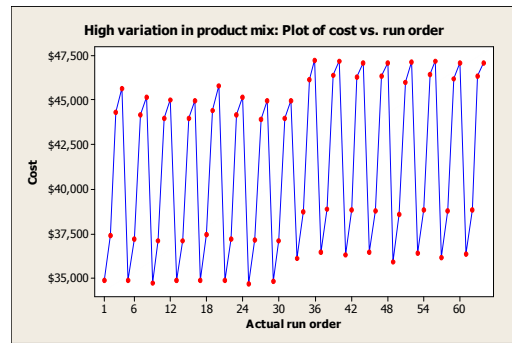
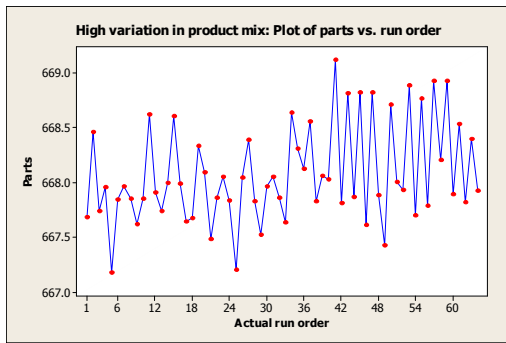
HIGH VARIATION IN PRODUCT MIX SCENARIO: EXPLORATORY DATA ANALYSIS

The histograms and probability plots show that none of the three responses display a normally distributed behaviour; therefore data transformation may be required for the three responses in this scenario.

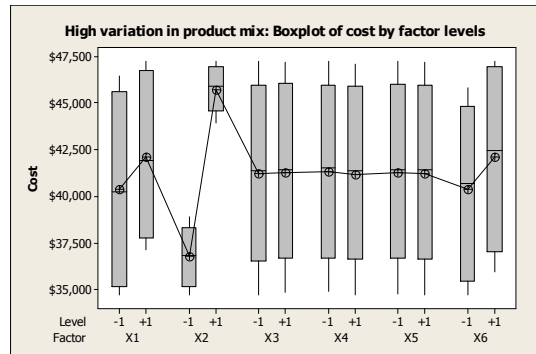
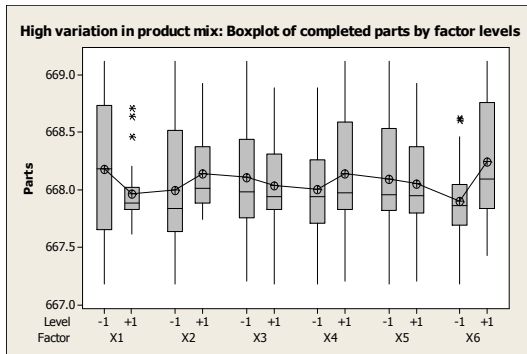


The time series plots do not show any relationship between the sequence of the experiments and the level of the three responses.

APPENDIX 59 (continued)

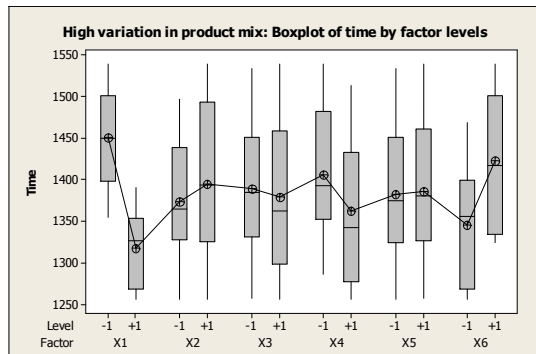


The box plots show that factors X1 (skill level of operators) and X6 (duration of set ups) may be of significance in terms of throughput. Factors X2 produce a significant change in the average cost. And, in terms of average time in the system, factors X1 and X6 may be the significant factors.



- Factors**

 - X1:** Skill level of operators
 - X2:** Buffer capacity
 - X3:** Number of AVGs
 - X4:** Speed of AVGs
 - X5:** Loading capacity of AVGs
 - X6:** Duration of set-ups



APPENDIX 60

HIGH VARIATION IN PRODUCT MIX SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant				668.08	
Operators skills	-0.239	-0.12	-7.648	0.914	7.49%
Buffer capacity	0.126	0.063	4.032	0.254	2.08%
Number of vehicles	-0.085	-0.043	-2.720	0.116	0.95%
Vehicle speed	0.123	0.062	3.936	0.242	1.98%
Loading capacity	-0.021	-0.01	-0.672	0.007	0.06%
Set up duration	0.36	0.18	11.520	2.074	16.99%
Operators skills*Buffer capacity	-0.205	-0.103	-6.560	0.672	5.51%
Operators skills*Number of vehicles	-0.116	-0.058	-3.712	0.215	1.76%
Operators skills*Vehicle speed	-0.24	-0.12	-7.680	0.922	7.55%
Operators skills*Loading capacity	-0.011	-0.005	-0.352	0.002	0.02%
Operators skills*Set up duration	-0.312	-0.156	-9.984	1.558	12.76%
Buffer capacity*Number of vehicles	0.032	0.016	1.024	0.016	0.13%
Buffer capacity*Vehicle speed	0.06	0.03	1.920	0.058	0.47%
Buffer capacity*Loading capacity	-0.008	-0.004	-0.256	0.001	0.01%
Buffer capacity*Set up duration	-0.207	-0.103	-6.624	0.686	5.62%
Number of vehicles*Vehicle speed	-0.009	-0.004	-0.288	0.001	0.01%
Number of vehicles*Loading capacity	0.001	0.001	0.032	0.000	0.00%
Number of vehicles*Set up duration	-0.008	-0.004	-0.256	0.001	0.01%
Vehicle speed*Loading capacity	-0.079	-0.04	-2.528	0.100	0.82%
Vehicle speed*Set up duration	0.027	0.014	0.864	0.012	0.10%
Loading capacity*Set up duration	0.052	0.026	1.664	0.043	0.35%
Operators skills*Buffer capacity*Number of vehicles	0.114	0.057	3.648	0.208	1.70%
Operators skills*Buffer capacity*Vehicle speed	-0.001	0	-0.032	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.016	-0.008	-0.512	0.004	0.03%
Operators skills*Buffer capacity*Set up duration	0.173	0.087	5.536	0.479	3.92%
Operators skills*Number of vehicles*Vehicle speed	0.164	0.082	5.248	0.430	3.53%
Operators skills*Number of vehicles*Loading capacity	-0.003	-0.002	-0.096	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.117	-0.059	-3.744	0.219	1.79%
Operators skills*Vehicle speed*Loading capacity	0.189	0.094	6.048	0.572	4.68%
Operators skills*Vehicle speed*Set up duration	-0.127	-0.064	-4.064	0.258	2.11%
Operators skills*Loading capacity*Set up duration	0.003	0.002	0.096	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	-0.029	-0.014	-0.928	0.013	0.11%
Buffer capacity*Number of vehicles*Loading capacity	-0.037	-0.019	-1.184	0.022	0.18%
Buffer capacity*Number of vehicles*Set up duration	0.037	0.018	1.184	0.022	0.18%
Buffer capacity*Vehicle speed*Loading capacity	-0.048	-0.024	-1.536	0.037	0.30%
Buffer capacity*Vehicle speed*Set up duration	-0.022	-0.011	-0.704	0.008	0.06%
Buffer capacity*Loading capacity*Set up duration	-0.058	-0.029	-1.856	0.054	0.44%
Number of vehicles*Vehicle speed*Loading capacity	-0.075	-0.038	-2.400	0.090	0.74%
Number of vehicles*Vehicle speed*Set up duration	-0.119	-0.059	-3.808	0.227	1.86%
Number of vehicles*Loading capacity*Set up duration	-0.005	-0.002	-0.160	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	0.033	0.017	1.056	0.017	0.14%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	-0.033	-0.016	-1.056	0.017	0.14%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0.011	0.006	0.352	0.002	0.02%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.095	0.047	3.040	0.144	1.18%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	-0.041	-0.021	-1.312	0.027	0.22%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	0.102	0.051	3.264	0.166	1.36%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.033	-0.016	-1.056	0.017	0.14%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.022	0.011	0.704	0.008	0.06%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.153	0.077	4.896	0.375	3.07%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.044	-0.022	-1.408	0.031	0.25%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.003	0.001	0.096	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.001	0	0.032	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.06	0.03	1.920	0.058	0.47%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0.097	0.048	3.104	0.151	1.23%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.067	0.033	2.144	0.072	0.59%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.021	-0.01	-0.672	0.007	0.06%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.073	0.036	2.336	0.085	0.70%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.119	-0.059	-3.808	0.227	1.86%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.027	-0.013	-0.864	0.012	0.10%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.002	0.001	0.064	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.082	0.041	2.624	0.108	0.88%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.092	-0.046	-2.944	0.135	1.11%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.023	0.011	0.736	0.008	0.07%
TOTAL				12.203	100%

APPENDIX 61

ANOVA TABLE FOR THE RESPONSE NUMBER OF COMPLETED PARTS; HIGH VARIATION IN PRODUCT MIX SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.91407	0.91407	19.61	0.000*
Buffer capacity	1	0.25228	0.25228	5.41	0.025
Number of vehicles	1	0.11660	0.11660	2.50	0.122
Vehicle speed	1	0.24266	0.24266	5.21	0.028
Loading capacity	1	0.00704	0.00704	0.15	0.700
Set up duration	1	2.07516	2.07516	44.53	0.000*
Operator skills*Buffer capacity	1	0.67558	0.67558	14.50	0.000*
Operator skills*Number of vehicles	1	0.21461	0.21461	4.60	0.038
Operator skills*Vehicle speed	1	0.92124	0.92124	19.77	0.000*
Operator skills>Loading capacity	1	0.00183	0.00183	0.04	0.844
Operator skills*Set up duration	1	1.56018	1.56018	33.48	0.000*
Buffer capacity*Set up duration	1	0.68405	0.68405	14.68	0.000*
Number of vehicles*Vehicle speed	1	0.00118	0.00118	0.03	0.875
Number of vehicles*Set up duration	1	0.00094	0.00094	0.02	0.888
Vehicle speed>Loading capacity	1	0.10045	0.10045	2.16	0.150
Vehicle speed*Set up duration	1	0.01209	0.01209	0.26	0.613
Operator skills*Buffer capacity* Set up duration	1	0.48108	0.48108	10.32	0.003*
Operator skills*Number of vehicles* Vehicle speed	1	0.43132	0.43132	9.25	0.004
Operator skills*Vehicle speed* Loading capacity	1	0.57059	0.57059	12.24	0.001*
Number of vehicles*Vehicle speed* Set up duration	1	0.22490	0.22490	4.83	0.034
Operator skills*Number of vehicles* Set up duration	1	0.21971	0.21971	4.71	0.036
Operator skills*Vehicle speed* Set up duration	1	0.25938	0.25938	5.57	0.023
Operator skills*Number of vehicles* Vehicle speed*Set up duration	1	0.37694	0.37694	8.09	0.007*
Error	40	1.86425	0.04661		
Total	63	12.20813			

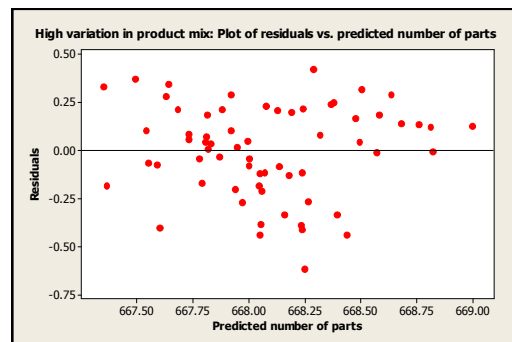
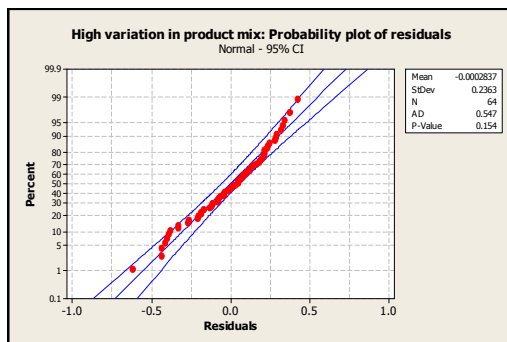
S = 0.215885 R-Sq = 84.73% R-Sq(adj) = 75.95%

* Significant factors

APPENDIX 62

HIGH VARIATION IN PRODUCT MIX SCENARIO: RESIDUALS FOR THE RESPONSE NUMBER OF COMPLETED PARTS

Run	y	\hat{y}	$e=y-\hat{y}$	Run	y	\hat{y}	$e=y-\hat{y}$
(1)	668	667.352	0.33	f	668	668.25	-0.62
a	668	668.242	0.22	af	669	668.476	0.16
b	668	667.938	-0.20	bf	668	668.076	0.23
ab	668	668.068	-0.12	abf	668	668.238	-0.11
c	667	667.362	-0.19	cf	669	668.568	-0.01
ac	668	668.232	-0.39	acf	668	668.158	-0.33
bc	668	667.948	0.02	bcf	668	668.394	-0.33
abc	668	668.058	-0.21	abcf	668	667.92	0.10
d	668	667.79	-0.17	df	669	668.996	0.13
ad	668	667.804	0.04	adf	668	667.73	0.08
bd	669	668.376	0.25	bdf	669	668.822	-0.01
abd	668	667.63	0.28	abdf	668	667.492	0.37
cd	668	667.78	-0.04	cdf	669	668.678	0.14
acd	668	667.814	0.18	acdf	668	668.048	-0.44
bcd	669	668.366	0.24	bcdf	669	668.504	0.32
abcd	668	667.64	0.34	abcdf	668	667.81	0.07
e	668	667.54	0.10	ef	668	668.438	-0.44
ae	668	668.054	-0.38	aef	669	668.288	0.42
be	668	668.126	0.21	bef	668	668.264	-0.26
abe	668	667.88	0.21	abef	668	668.05	-0.12
ce	667	667.55	-0.06	cef	669	668.756	0.13
ace	668	668.044	-0.19	acef	668	667.97	-0.27
bce	668	668.136	-0.08	bcef	669	668.582	0.19
abce	668	667.87	-0.03	abcef	668	667.732	0.06
de	667	667.602	-0.40	def	669	668.808	0.12
ade	668	667.992	0.05	adef	668	667.918	0.29
bde	668	668.188	0.20	bdef	669	668.634	0.29
abde	668	667.818	0.01	abdef	668	667.68	0.21
cde	668	667.592	-0.07	cdef	669	668.49	0.04
acde	668	668.002	-0.04	acdef	668	668.236	-0.41
bcde	668	668.178	-0.13	bcdef	668	668.316	0.08
abcde	668	667.828	0.03	abcdef	668	667.998	-0.08



APPENDIX 63

HIGH VARIATION IN PRODUCT MIX SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		4.61253			
Operators skills	0.01906	0.00953	0.610	0.006	3.75%
Buffer capacity	0.09422	0.04711	3.015	0.142	91.56%
Number of vehicles	0.00033	0.00016	0.011	0.000	0.00%
Vehicle speed	-0.00118	-0.00059	-0.038	0.000	0.01%
Loading capacity	-0.00026	-0.00013	-0.008	0.000	0.00%
Set up duration	0.01863	0.00932	0.596	0.006	3.58%
Operators skills*Buffer capacity	-0.00977	-0.00489	-0.313	0.002	0.98%
Operators skills*Number of vehicles	-0.00111	-0.00055	-0.036	0.000	0.01%
Operators skills*Vehicle speed	-0.00057	-0.00028	-0.018	0.000	0.00%
Operators skills*Loading capacity	0.00027	0.00014	0.009	0.000	0.00%
Operators skills*Set up duration	-0.00059	-0.0003	-0.019	0.000	0.00%
Buffer capacity*Number of vehicles	-0.00074	-0.00037	-0.024	0.000	0.01%
Buffer capacity*Vehicle speed	-0.00079	-0.0004	-0.025	0.000	0.01%
Buffer capacity*Loading capacity	0.00013	0.00007	0.004	0.000	0.00%
Buffer capacity*Set up duration	0.0008	0.0004	0.026	0.000	0.01%
Number of vehicles*Vehicle speed	0.00022	0.00011	0.007	0.000	0.00%
Number of vehicles*Loading capacity	0.00016	0.00008	0.005	0.000	0.00%
Number of vehicles*Set up duration	0.00138	0.00069	0.044	0.000	0.02%
Vehicle speed*Loading capacity	-0.00006	-0.00003	-0.002	0.000	0.00%
Vehicle speed*Set up duration	0.00152	0.00076	0.049	0.000	0.02%
Loading capacity*Set up duration	-0.0004	-0.0002	-0.013	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles	0.00006	0.00003	0.002	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed	-0.00019	-0.00009	-0.006	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.00009	-0.00005	-0.003	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00066	-0.00033	-0.021	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed	0.00039	0.00019	0.012	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity	-0.00007	-0.00004	-0.002	0.000	0.00%
Operators skills*Number of vehicles*Set up duration	-0.00002	-0.00001	-0.001	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	0.00006	0.00003	0.002	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00011	0.00006	0.004	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00006	0.00003	0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	0.00038	0.00019	0.012	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	-0.00007	-0.00003	-0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00008	0.00004	0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00006	-0.00003	-0.002	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00025	0.00012	0.008	0.000	0.00%
Buffer capacity*Loading capacity*Set up duration	0.0001	0.00005	0.003	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00002	0.00001	0.001	0.000	0.00%
Number of vehicles*Vehicle speed*Set up duration	-0.00127	-0.00063	-0.041	0.000	0.02%
Number of vehicles*Loading capacity*Set up duration	0.00029	0.00014	0.009	0.000	0.00%
Vehicle speed*Loading capacity*Set up duration	0.00026	0.00013	0.008	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00027	0.00013	0.009	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	-0.00006	-0.00003	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0.00001	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.0001	-0.00005	-0.003	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity*Set up duration	-0.00005	-0.00002	-0.002	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00004	0.00002	0.001	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	0.00001	0.00001	0.000	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00006	-0.00003	-0.002	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00005	0.00002	0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.0001	0.00005	0.003	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00003	-0.00001	-0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00001	0	0.000	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0	0	0.000	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00023	-0.00011	-0.007	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00001	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	-0.00005	-0.00002	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	0	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00001	0	0.000	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00004	0.00002	0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00007	-0.00004	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00003	0.00001	0.001	0.000	0.00%
TOTAL				0.155	100%

APPENDIX 64

ANOVA TABLE FOR THE RESPONSE COST; HIGH VARIATION IN PRODUCT MIX SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.005813	0.005813	1700.21	0.000*
Buffer capacity	1	0.142045	0.142045	41546.29	0.000*
Set up duration	1	0.005555	0.005555	1624.63	0.000*
Operator skills*Buffer capacity	1	0.001529	0.001529	447.11	0.000*
Error	59	0.000202	0.000003		
Total	63	0.155143			

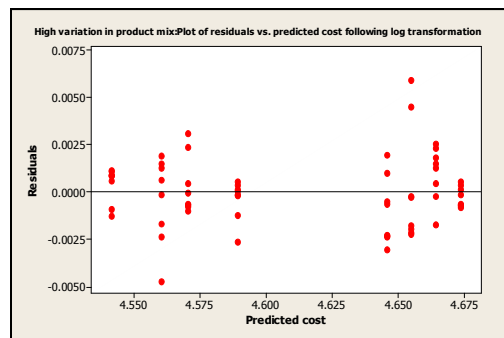
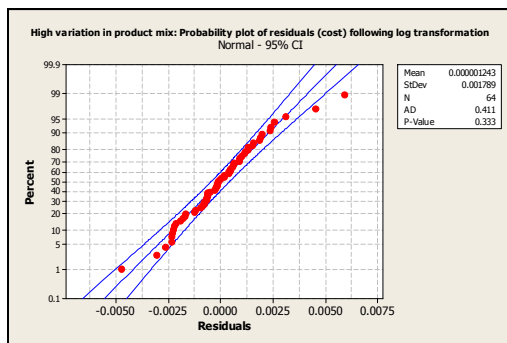
S = 0.00184904 R-Sq = 99.87% R-Sq(adj) = 99.86%

* Significant factors

APPENDIX 65

HIGH VARIATION IN PRODUCT MIX SCENARIO: RESIDUALS FOR THE RESPONSE MANUFACTURING COST FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	4.5426	4.5417	0.0009	f	4.5580	4.5603	-0.0023
a	4.5729	4.5705	0.0024	af	4.5880	4.5892	-0.0012
b	4.6467	4.6457	0.0010	bf	4.6641	4.6643	-0.0002
ab	4.6595	4.6550	0.0045	abf	4.6742	4.6736	0.0006
c	4.5426	4.5417	0.0009	cf	4.5622	4.5603	0.0019
ac	4.5705	4.5705	0.0000	acf	4.5897	4.5892	0.0005
bc	4.6452	4.6457	-0.0005	bcf	4.6667	4.6643	0.0024
abc	4.6547	4.6550	-0.0003	abcf	4.6740	4.6736	0.0004
d	4.5408	4.5417	-0.0009	df	4.5602	4.5603	-0.0001
ad	4.5699	4.5705	-0.0007	adf	4.5893	4.5892	0.0002
bd	4.6434	4.6457	-0.0023	bdf	4.6656	4.6643	0.0013
abd	4.6532	4.6550	-0.0018	abdf	4.6730	4.6736	-0.0006
cd	4.5428	4.5417	0.0011	cdf	4.5619	4.5603	0.0015
acd	4.5695	4.5705	-0.0010	acdf	4.5890	4.5892	-0.0001
bcd	4.6434	4.6457	-0.0023	bcdf	4.6662	4.6643	0.0018
abcd	4.6527	4.6550	-0.0022	abcdf	4.6728	4.6736	-0.0008
e	4.5429	4.5417	0.0012	ef	4.5556	4.5603	-0.0047
ae	4.5736	4.5705	0.0031	aef	4.5865	4.5892	-0.0026
be	4.6476	4.6457	0.0020	bef	4.6626	4.6643	-0.0017
abe	4.6609	4.6550	0.0059	abef	4.6735	4.6736	-0.0001
ce	4.5426	4.5417	0.0009	cef	4.5616	4.5603	0.0013
ace	4.5710	4.5705	0.0005	acef	4.5895	4.5892	0.0004
bce	4.6451	4.6457	-0.0006	bcef	4.6669	4.6643	0.0026
abce	4.6547	4.6550	-0.0002	abcef	4.6738	4.6736	0.0002
de	4.5404	4.5417	-0.0012	def	4.5587	4.5603	-0.0017
ade	4.5699	4.5705	-0.0006	adef	4.5890	4.5892	-0.0001
bde	4.6426	4.6457	-0.0030	bdef	4.6648	4.6643	0.0005
abde	4.6530	4.6550	-0.0019	abdef	4.6729	4.6736	-0.0007
cde	4.5423	4.5417	0.0006	cdef	4.5610	4.5603	0.0007
acde	4.5697	4.5705	-0.0008	acdef	4.5892	4.5892	0.0001
bcde	4.6433	4.6457	-0.0024	bcdef	4.6658	4.6643	0.0015
abcde	4.6528	4.6550	-0.0021	abcdef	4.6729	4.6736	-0.0007



APPENDIX 66

HIGH VARIATION IN PRODUCT MIX SCENARIO: FACTOR EFFECT ESTIMATES AND SUM OF SQUARES FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Model Term	Effect Estimate	Coef	Contrast	Sum of Squares	Percent Contribution
Constant		3.14034			
Operators skills	-0.0416	-0.0208	-1.331	0.028	64.43%
Buffer capacity	0.00633	0.00316	0.203	0.001	1.49%
Number of vehicles	-0.0035	-0.00175	-0.112	0.000	0.46%
Vehicle speed	-0.01397	-0.00699	-0.447	0.003	7.27%
Loading capacity	0.0013	0.00065	0.042	0.000	0.06%
Set up duration	0.0238	0.0119	0.762	0.009	21.09%
Operators skills*Buffer capacity	-0.00652	-0.00326	-0.209	0.001	1.58%
Operators skills*Number of vehicles	-0.00428	-0.00214	-0.137	0.000	0.68%
Operators skills*Vehicle speed	-0.0026	-0.0013	-0.083	0.000	0.25%
Operators skills*Loading capacity	0.00069	0.00035	0.022	0.000	0.02%
Operators skills*Set up duration	-0.00413	-0.00206	-0.132	0.000	0.64%
Buffer capacity*Number of vehicles	-0.00057	-0.00028	-0.018	0.000	0.01%
Buffer capacity*Vehicle speed	0.00011	0.00005	0.004	0.000	0.00%
Buffer capacity*Loading capacity	0.00034	0.00017	0.011	0.000	0.00%
Buffer capacity*Set up duration	0.00038	0.00019	0.012	0.000	0.01%
Number of vehicles*Vehicle speed	0.00509	0.00255	0.163	0.000	0.96%
Number of vehicles*Loading capacity	-0.0008	-0.0004	-0.026	0.000	0.02%
Number of vehicles*Set up duration	0.00254	0.00127	0.081	0.000	0.24%
Vehicle speed*Loading capacity	-0.00091	-0.00045	-0.029	0.000	0.03%
Vehicle speed*Set up duration	0.00298	0.00149	0.095	0.000	0.33%
Loading capacity*Set up duration	-0.00061	-0.00031	-0.020	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles	0.00073	0.00037	0.023	0.000	0.02%
Operators skills*Buffer capacity*Vehicle speed	-0.0003	-0.00015	-0.010	0.000	0.00%
Operators skills*Buffer capacity*Loading capacity	-0.00033	-0.00017	-0.011	0.000	0.00%
Operators skills*Buffer capacity*Set up duration	-0.00052	-0.00026	-0.017	0.000	0.01%
Operators skills*Number of vehicles*Vehicle speed	0.00177	0.00088	0.057	0.000	0.12%
Operators skills*Number of vehicles*Loading capacity	-0.00042	-0.00021	-0.013	0.000	0.01%
Operators skills*Number of vehicles*Set up duration	-0.00025	-0.00013	-0.008	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity	-0.00035	-0.00018	-0.011	0.000	0.00%
Operators skills*Vehicle speed*Set up duration	0.00026	0.00013	0.008	0.000	0.00%
Operators skills*Loading capacity*Set up duration	0.00015	0.00007	0.005	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed	-0.00024	-0.00012	-0.008	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity	0.00001	0	0.000	0.000	0.00%
Buffer capacity*Number of vehicles*Set up duration	0.00004	0.00002	0.001	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity	-0.00002	-0.00001	-0.001	0.000	0.00%
Buffer capacity*Vehicle speed*Set up duration	0.00041	0.00021	0.013	0.000	0.01%
Buffer capacity*Loading capacity*Set up duration	0.00019	0.00009	0.006	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity	0.00008	0.00004	0.026	0.000	0.02%
Number of vehicles*Vehicle speed*Set up duration	-0.00205	-0.00103	-0.066	0.000	0.16%
Number of vehicles*Loading capacity*Set up duration	0.00054	0.00027	0.017	0.000	0.01%
Vehicle speed*Loading capacity*Set up duration	0.00033	0.00016	0.011	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed	0.00042	0.00021	0.013	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity	0	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Set up duration	0	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity	0.00017	0.00009	0.005	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Set up duration	-0.00047	-0.00024	-0.015	0.000	0.01%
Operators skills*Buffer capacity*Loading capacity*Set up duration	0.00002	0.00001	0.001	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity	0.00028	0.00014	0.009	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Set up duration	-0.00017	-0.00009	-0.005	0.000	0.00%
Operators skills*Number of vehicles*Loading capacity*Set up duration	-0.00013	-0.00006	-0.004	0.000	0.00%
Operators skills*Vehicle speed*Loading capacity*Set up duration	0.00002	0.00001	0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	0.00005	0.00003	0.002	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00004	0.00002	0.001	0.000	0.00%
Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.0001	-0.00005	-0.003	0.000	0.00%
Buffer capacity*Vehicle speed*Loading capacity*Set up duration	-0.00013	-0.00006	-0.004	0.000	0.00%
Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00041	-0.00021	-0.013	0.000	0.01%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity	-0.00013	-0.00007	-0.004	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Set up duration	0.00001	0	0.000	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Loading capacity*Set up duration	-0.00005	-0.00003	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Vehicle speed*Loading capacity*Set up duration	0.00006	0.00003	0.002	0.000	0.00%
Operators skills*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00014	0.00007	0.004	0.000	0.00%
Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	-0.00005	-0.00002	-0.002	0.000	0.00%
Operators skills*Buffer capacity*Number of vehicles*Vehicle speed*Loading capacity*Set up duration	0.00004	0.00002	0.001	0.000	0.00%
TOTAL				0.043	100%

APPENDIX 67

ANOVA TABLE FOR THE RESPONSE TIME; HIGH VARIATION IN PRODUCT MIX SCENARIO

Source	DF	SS	MS	F	P
Operator skills	1	0.0276829	0.0276829	7672.48	0.000*
Buffer capacity	1	0.0006410	0.0006410	177.65	0.000*
Number of vehicles	1	0.0001962	0.0001962	54.37	0.000*
Vehicle speed	1	0.0031236	0.0031236	865.73	0.000*
Set up duration	1	0.0090648	0.0090648	2512.37	0.000*
Operator skills*Buffer capacity	1	0.0006803	0.0006803	188.54	0.000*
Operator skills*Number of vehicles	1	0.0002929	0.0002929	81.18	0.000*
Operator skills*Vehicle speed	1	0.0001080	0.0001080	29.94	0.000*
Operator skills*Set up duration	1	0.0002728	0.0002728	75.61	0.000*
Number of vehicles*Vehicle speed	1	0.0004148	0.0004148	114.97	0.000*
Number of vehicles*Set up duration	1	0.0001030	0.0001030	28.55	0.000*
Vehicle speed*Set up duration	1	0.0001417	0.0001417	39.26	0.000*
Number of vehicles*Vehicle speed*	1	0.0000674	0.0000674	18.68	0.000*
Set up duration					
Error	50	0.0001804	0.0000036		
Total	63	0.0429697			

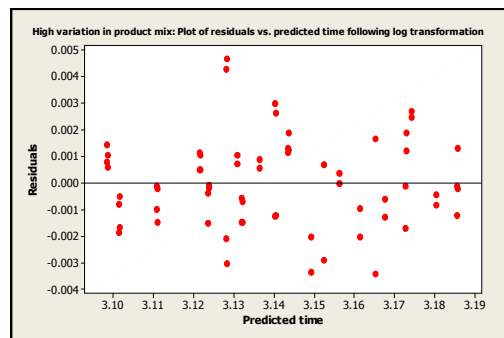
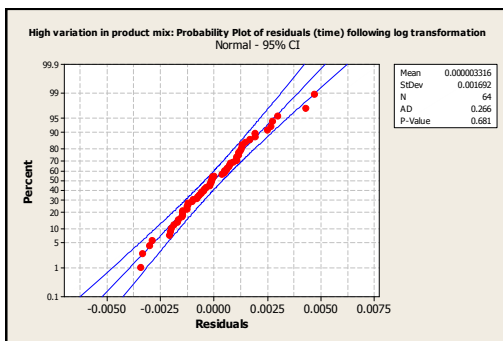
S = 0.00189949 R-Sq = 99.58% R-Sq(adj) = 99.47%

* Significant factors

APPENDIX 68

HIGH VARIATION IN PRODUCT MIX SCENARIO: RESIDUALS FOR THE RESPONSE AVERAGE TIME IN THE SYSTEM FOLLOWING A LOG TRANSFORMATION

Run	y	\hat{y}	e=y- \hat{y}	Run	y	\hat{y}	e=y- \hat{y}
(1)	3.1495	3.1524	-0.0029	f	3.1726	3.1727	-0.0001
a	3.1253	3.1283	-0.0030	af	3.1392	3.1404	-0.0012
b	3.1618	3.1652	-0.0034	bf	3.1844	3.1856	-0.0012
ab	3.1260	3.1281	-0.0021	abf	3.1390	3.1402	-0.0012
c	3.1448	3.1435	0.0013	cf	3.1749	3.1730	0.0019
ac	3.1094	3.1108	-0.0015	acf	3.1307	3.1321	-0.0015
bc	3.1563	3.1563	0.0000	bcf	3.1857	3.1859	-0.0002
abc	3.1096	3.1106	-0.0010	abcf	3.1305	3.1319	-0.0015
d	3.1316	3.1309	0.0007	df	3.1603	3.1613	-0.0010
ad	3.0999	3.1016	-0.0017	adf	3.1236	3.1238	-0.0002
bd	3.1450	3.1437	0.0013	bdf	3.1769	3.1741	0.0027
abd	3.0995	3.1014	-0.0019	abdf	3.1221	3.1236	-0.0015
cd	3.1372	3.1363	0.0009	cdf	3.1670	3.1677	-0.0006
acd	3.0991	3.0984	0.0006	acdf	3.1221	3.1216	0.0005
bcd	3.1458	3.1491	-0.0033	bcdf	3.1797	3.1805	-0.0008
abcd	3.0990	3.0982	0.0008	abcdf	3.1219	3.1214	0.0005
e	3.1531	3.1524	0.0007	ef	3.1710	3.1727	-0.0017
ae	3.1330	3.1283	0.0047	aef	3.1431	3.1404	0.0026
be	3.1669	3.1652	0.0017	bef	3.1855	3.1856	-0.0001
abe	3.1324	3.1281	0.0043	abef	3.1432	3.1402	0.0030
ce	3.1446	3.1435	0.0011	cef	3.1742	3.1730	0.0012
ace	3.1106	3.1108	-0.0002	acef	3.1314	3.1321	-0.0007
bce	3.1567	3.1563	0.0004	bcef	3.1872	3.1859	0.0013
abce	3.1105	3.1106	-0.0001	abcef	3.1314	3.1319	-0.0006
de	3.1319	3.1309	0.0010	def	3.1593	3.1613	-0.0020
ade	3.1011	3.1016	-0.0005	adef	3.1237	3.1238	-0.0001
bde	3.1456	3.1437	0.0019	bdef	3.1766	3.1741	0.0025
abde	3.1006	3.1014	-0.0008	abdef	3.1232	3.1236	-0.0004
cde	3.1369	3.1363	0.0006	cdef	3.1664	3.1677	-0.0013
acde	3.0995	3.0984	0.0011	acdef	3.1226	3.1216	0.0010
bcde	3.1471	3.1491	-0.0020	bcdef	3.1800	3.1805	-0.0005
abcde	3.0997	3.0982	0.0015	abcdef	3.1225	3.1214	0.0012



APPENDIX 69

EXPERIMENTAL RESULTS; BASELINE MODEL

RUN	LABEL	EXPERIMENTAL FACTOR						Baseline model		
		X1	X2	X3	X4	X5	X6	Parts	Time	Cost
1	(1)	-1	-1	-1	-1	-1	-1	665	1,454	\$35,575
2	a	+1	-1	-1	-1	-1	-1	666	1,372	\$38,309
3	b	-1	+1	-1	-1	-1	-1	665	1,492	\$40,513
4	ab	+1	+1	-1	-1	-1	-1	667	1,380	\$42,741
5	c	-1	-1	+1	-1	-1	-1	665	1,433	\$35,466
6	ac	+1	-1	+1	-1	-1	-1	667	1,318	\$38,126
7	bc	-1	+1	+1	-1	-1	-1	667	1,454	\$40,308
8	abc	+1	+1	+1	-1	-1	-1	667	1,317	\$42,201
9	d	-1	-1	-1	+1	-1	-1	667	1,405	\$35,457
10	ad	+1	-1	-1	+1	-1	-1	667	1,291	\$38,080
11	bd	-1	+1	-1	+1	-1	-1	665	1,425	\$40,108
12	abd	+1	+1	-1	+1	-1	-1	667	1,289	\$42,113
13	cd	-1	-1	+1	+1	-1	-1	665	1,402	\$35,375
14	acd	+1	-1	+1	+1	-1	-1	667	1,288	\$38,097
15	bcd	-1	+1	+1	+1	-1	-1	667	1,425	\$40,141
16	abcd	+1	+1	+1	+1	-1	-1	667	1,288	\$42,126
17	e	-1	-1	-1	-1	+1	-1	667	1,459	\$35,467
18	ae	+1	-1	-1	-1	+1	-1	667	1,375	\$38,205
19	be	-1	+1	-1	-1	+1	-1	667	1,487	\$40,341
20	abe	+1	+1	-1	-1	+1	-1	667	1,378	\$42,468
21	ce	-1	-1	+1	-1	+1	-1	666	1,440	\$35,557
22	ace	+1	-1	+1	-1	+1	-1	667	1,320	\$38,097
23	bce	-1	+1	+1	-1	+1	-1	666	1,459	\$40,301
24	abce	+1	+1	+1	-1	+1	-1	667	1,320	\$42,178
25	de	-1	-1	-1	+1	+1	-1	666	1,396	\$35,328
26	ade	+1	-1	-1	+1	+1	-1	667	1,293	\$38,078
27	bde	-1	+1	-1	+1	+1	-1	666	1,551	\$37,055
28	abde	+1	+1	-1	+1	+1	-1	667	1,292	\$42,118
29	cde	-1	-1	+1	+1	+1	-1	666	1,405	\$35,409
30	acde	+1	-1	+1	+1	+1	-1	667	1,290	\$38,063
31	bcde	-1	+1	+1	+1	+1	-1	666	1,431	\$40,190
32	abcde	+1	+1	+1	+1	+1	-1	667	1,289	\$42,092
33	f	-1	-1	-1	-1	-1	+1	666	1,551	\$37,055
34	af	+1	-1	-1	-1	-1	+1	666	1,423	\$39,840
35	bf	-1	+1	-1	-1	-1	+1	665	1,573	\$42,269
36	abf	+1	+1	-1	-1	-1	+1	667	1,426	\$44,351
37	cf	-1	-1	+1	-1	-1	+1	666	1,536	\$37,166
38	acf	+1	-1	+1	-1	-1	+1	667	1,382	\$39,759
39	bcf	-1	+1	+1	-1	-1	+1	666	1,561	\$42,303
40	abcf	+1	+1	+1	-1	-1	+1	668	1,381	\$44,083
41	df	-1	-1	-1	+1	-1	+1	667	1,507	\$37,099
42	adf	+1	-1	-1	+1	-1	+1	668	1,361	\$39,838
43	bdf	-1	+1	-1	+1	-1	+1	665	1,537	\$42,264
44	abdf	+1	+1	-1	+1	-1	+1	667	1,356	\$44,045
45	cdf	-1	-1	+1	+1	-1	+1	665	1,518	\$37,158
46	acdf	+1	-1	+1	+1	-1	+1	667	1,356	\$39,791
47	bcdf	-1	+1	+1	+1	-1	+1	666	1,536	\$42,241
48	abcdf	+1	+1	+1	+1	-1	+1	667	1,356	\$44,047

APPENDIX 69 (continued)

RUN	LABEL	EXPERIMENTAL FACTOR						Baseline model		
		X1	X2	X3	X4	X5	X6	Parts	Time	Cost
49	<i>ef</i>	-1	-1	-1	-1	+1	+1	665	1,535	\$36,606
50	<i>aef</i>	+1	-1	-1	-1	+1	+1	666	1,421	\$39,386
51	<i>bef</i>	-1	+1	-1	-1	+1	+1	667	1,556	\$41,851
52	<i>abef</i>	+1	+1	-1	-1	+1	+1	667	1,418	\$43,839
53	<i>cef</i>	-1	-1	+1	-1	+1	+1	666	1,545	\$37,209
54	<i>acef</i>	+1	-1	+1	-1	+1	+1	667	1,388	\$39,849
55	<i>bcef</i>	-1	+1	+1	-1	+1	+1	666	1,566	\$42,337
56	<i>abcef</i>	+1	+1	+1	-1	+1	+1	667	1,387	\$44,140
57	<i>def</i>	-1	-1	-1	+1	+1	+1	665	1,496	\$36,786
58	<i>adef</i>	+1	-1	-1	+1	+1	+1	666	1,363	\$39,661
59	<i>bdef</i>	-1	+1	-1	+1	+1	+1	666	1,543	\$42,268
60	<i>abdef</i>	+1	+1	-1	+1	+1	+1	667	1,359	\$44,055
61	<i>cdef</i>	-1	-1	+1	+1	+1	+1	666	1,524	\$37,154
62	<i>acdef</i>	+1	-1	+1	+1	+1	+1	667	1,358	\$39,811
63	<i>bcdef</i>	-1	+1	+1	+1	+1	+1	667	1,539	\$42,246
64	<i>abcdef</i>	+1	+1	+1	+1	+1	+1	667	1,357	\$44,048