MIE 360: PROJECT 2016

RESULTS, SUGGESTIONS, AND CONCLUSION

DATE: DEC 7, 2016

Hsiang-Yi Wang - 1000821587

Jiming Zhou - 1001595393

Alex Kwan - 1001559057

Define

For design of experiments (DoE) our team decided to use the 4 factors: C1 batch size, C2 batch size, C3 batch size and the number of assembly lines. Each factor has two levels: a high(+1) and a low level(-1). For the batch size factors, the high levels are the original batch sizes given by the client: C1: 200 units, C2: 300 units and C3: 100 units. The low levels are the sizes given above but halved (100, 150, 50). The high and low level for the number of assembly lines is 3 and 1.

Since there are 4 factors (k=4) in the DoE, there are 16 combinations/configurations (2^k) and each model configuration was run 10 times. We chose 10 runs for each configuration so as have enough degrees of freedom to calculate the coefficients (beta's) of each factor as well as the p-values to determine if each factor was important and statistically significant.

The measured response of each configuration run was total production of assembled parts, with both good and defective parts counted. In Simul8 this value was the number of completed jobs the Quality Control activity completed each run.

After running all configurations and recording the results, we used regression analysis to see which factor(s) and/or which interaction(s) had the largest effect on total production (with a high coefficient/beta) while still being statistically significant. We then compared the results between the configurations in order to provide suggestions to improve the current manufacturing process.

Regression Model and Configuration

After recording the response for each of the 160 runs, our team used a linear regression analysis to see which factors or any interactions of factors have the greatest effect on the Simul8 model's total production.

The resulting linear regression meta model has the following formula:

$$
\begin{aligned}
Y = \quad & b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 \\
& + b_5x_1x_2 + b_6x_1x_3 + b_7x_1x_4 + b_8x_2x_3 + b_9x_2x_4 + b_{10}x_3x_4 \\
& + b_{11}x_1x_2x_3 + b_{12}x_1x_2x_4 + b_{13}x_1x_3x_4 + b_{14}x_2x_3x_4 \\
& + b_{15}x_1x_2x_3x_4 + e
\end{aligned}
$$

Where:

- *Y is the response*
- b_0 is the intercept
- b_i *(betas) is the coefficient for each factor*
- X_i *are the factors*
- $X_1 = A =$ *C1 batch size level*
- $X_2 = B =$ *C2 batch size level*
- $X_3 = C =$ *C3 batch size level*
- $X_4 = D =$ *Number of assembly lines level*
- $e =$ *error*

The coefficient b_i represents the proportionate change in the response if x_i changes. Therefore a factor x_i is important if it has a high positive or negative coefficient since changing x_i will have a large effect on the response.

The null hypothesis for each b_i *is:*

H_o: $bi = 0$

While the alternative hypothesis is:

H_a: $bi != 0$

This hypothesis is tested using t-tests which gives the p-value indicating if each b_i is statistically significant (p-value < 0.05).

Regression Observations and Discussion

Figure #1 is a screenshot of the regression analysis. Regression observations include:

- All the p-values are small thus we reject the null hypothesis for each of the coefficients (betas), that it equals zero. And therefore, an adjusted regression model which removes statistically insignificant factors is not needed.
- Factors A*B and B*C have the largest effect. Therefore we conclude that changing C1, C2 and C3 batch sizes all together has a larger effect compared to changing individual batch sizes.
- Also, the negative effect of changing factor A or factor C represents that altering the batch sizes disproportionately (batch sizes don't have a 2:3:1 ratio) will result in an unbalanced component production output which reduces the total parts assembled since one component will be processed in excessive amounts.

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	734.2625	0.586413002	1252.125205	0.00%	733.1034107	735.4215893	733.1034107	735.4215893
A	-48.2	0.586413002	-82.19463054	0.00%	-49.35908932	-47.04091068	-49.35908932	-47.04091068
B	2.875	0.586413002	4.902688025	0.00%	1.715910683	4.034089317	1.715910683	4.034089317
C	-10.8375	0.586413002	-18.48100225	0.00%	-11.99658932	-9.678410683	-11.99658932	-9.678410683
D	21.9875	0.586413002	37.49490537	0.00%	20.82841068	23.14658932	20.82841068	23.14658932
AB	86.3375	0.586413002	147.229853	0.00%	85.17841068	87.49658932	85.17841068	87.49658932
AC	47.2	0.586413002	80.48934774	0.00%	46.04091068	48.35908932	46.04091068	48.35908932
AD	4.45	0.586413002	7.588508421	0.00%	3.290910683	5.609089317	3.290910683	5.609089317
BC	73.475	0.586413002	125.2956531	0.00%	72.31591068	74.63408932	72.31591068	74.63408932
BD	3.375	0.586413002	5.75532942	0.00%	2.215910683	4.534089317	2.215910683	4.534089317
CD	4.5875	0.586413002	7.822984805	0.00%	3.428410683	5.746589317	3.428410683	5.746589317
ABC	15.4375	0.586413002	26.32530309	0.00%	14.27841068	16.59658932	14.27841068	16.59658932
ABD	19.9125	0.586413002	33.95644358	0.00%	18.75341068	21.07158932	18.75341068	21.07158932
ACD	21.55	0.586413002	36.74884415	0.00%	20.39091068	22.70908932	20.39091068	22.70908932
BCD	20.275	0.586413002	34.57460859	0.00%	19.11591068	21.43408932	19.11591068	21.43408932
ABCD	3.3125	0.586413002	5.648749246	0.00%	2.153410683	4.471589317	2.153410683	4.471589317

A	C1 batch size
B	C2 batch size
C	C3 batch size
D	Number of Assembly lines

Figure #1: Regression Analysis

Figure #2 provides the 16 configurations of the 4 factors. Configuration observations include:

- Configuration 9 and 16 give the best total production (1050 and 1000 parts respectively which can be found in the attached excel spreadsheet)
- Both configurations have 3 assembly lines and for configuration 9, it has the low level of the batch sizes (100, 150, 50) while Configuration 16 has the high level of the batch sizes (200. 300. 100)
- Configuration 1 gives the best production (about 915 which can be found in the attached excel spreadsheet) among all configurations using only one assembly line.
- Configuration 1 has the same batch sizes as Configuration 9 (100, 150, 50).

Configuration	A	B	C	D
	C1 batch size	C2 batch size	C3 batch size	# of Assembly Lines
1	100	150	50	1
2	200	150	50	1
3	100	300	50	1
4	200	300	50	1
5	100	150	100	1
6	200	150	100	1
7	100	300	100	1
8	200	300	100	1
9	100	150	50	3
10	200	150	50	3
11	100	300	50	3
12	200	300	50	3
13	100	150	100	3
14	200	150	100	3
15	100	300	100	3
16	200	300	100	3

Figure #2: Factor combinations for each configuration

Suggestions and Conclusion

Since Configuration 9 has the highest total production at 1050 parts, it is the best model.

The measures of this model are summarized below with additional info in the appendix (including corresponding distributions):

- Mean Total time in system for each component: 2128.91 minutes
- Mean Total wait time for each component 1: 395.98 minutes
- Mean Total wait time for each component 2: 591.22 minutes
- Mean Total wait time for each component 3: 1152.08 minutes
- Mean Total weight of the final product (after packaging): 244.08 grams
- Total production in a five day week : 250 items
- Machine utilization:
    - Machine 1: 64.19%
    - Machine 2: 65.06%
    - Machine 3: 47.39%
    - Assembly 1: 27.55%
    - Assembly 2: 19.71%
    - Assembly 3: 27.17%

However this configuration does use 3 assembly lines which would cost more money. Therefore we suggest an economical analysis to discover if the benefit of increased total production outweighs the cost of the additional assembly line. This economical analysis would utilize the complete meta model given previously to explore the effect for different amounts of assembly lines (1, 2, or 3 assembly lines) in order to find the most beneficial/cost effective solution.

Note: Eg. For 2 assembly lines, X_4 = 0 in the meta model.

Another improvement would be to shrink the batch sizes to 100,150,50 as used in Configuration 1 and Configuration 9. Since when compared to all configurations with the same number of assembly lines they produced the most parts.

The difference in total production of Configuration 1 and 9 (which differ only in the number of assembly lines) is around 135, which is relatively low. Therefore it is clear, that decreasing the batch sizes in proportion will increase total production regardless of the number of assembly lines.

In the future, other factors that be explored are:

- changing the sequence a machine processes components (C1 then C2 versus C2 then C1)
- changing the number of machines (having three machine 2)
- changing the numbers of worker and their shifts

Appendix A - Some Distributions and Numbers for Measuring the Optimal Model

TOTAL TIME IN SYSTEM FOR EACH COMPONENT

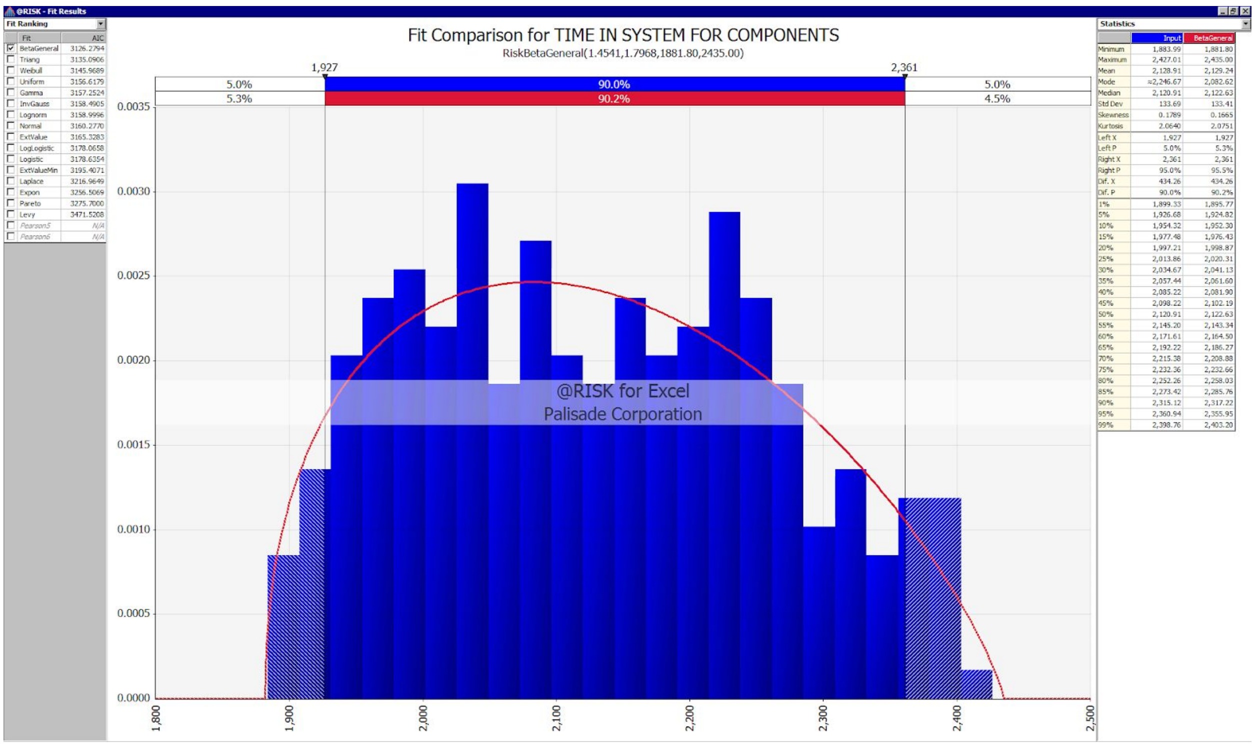

Figure 3 - Distribution for the total time in system for each component

The mean for the total time is 2128.91 minutes, the standard deviation is 133.69, and group fitted a BetaGeneral (1.45, 1.79, 1881.8, 2435) distribution to it.

WAIT TIME OF COMPONENT 1

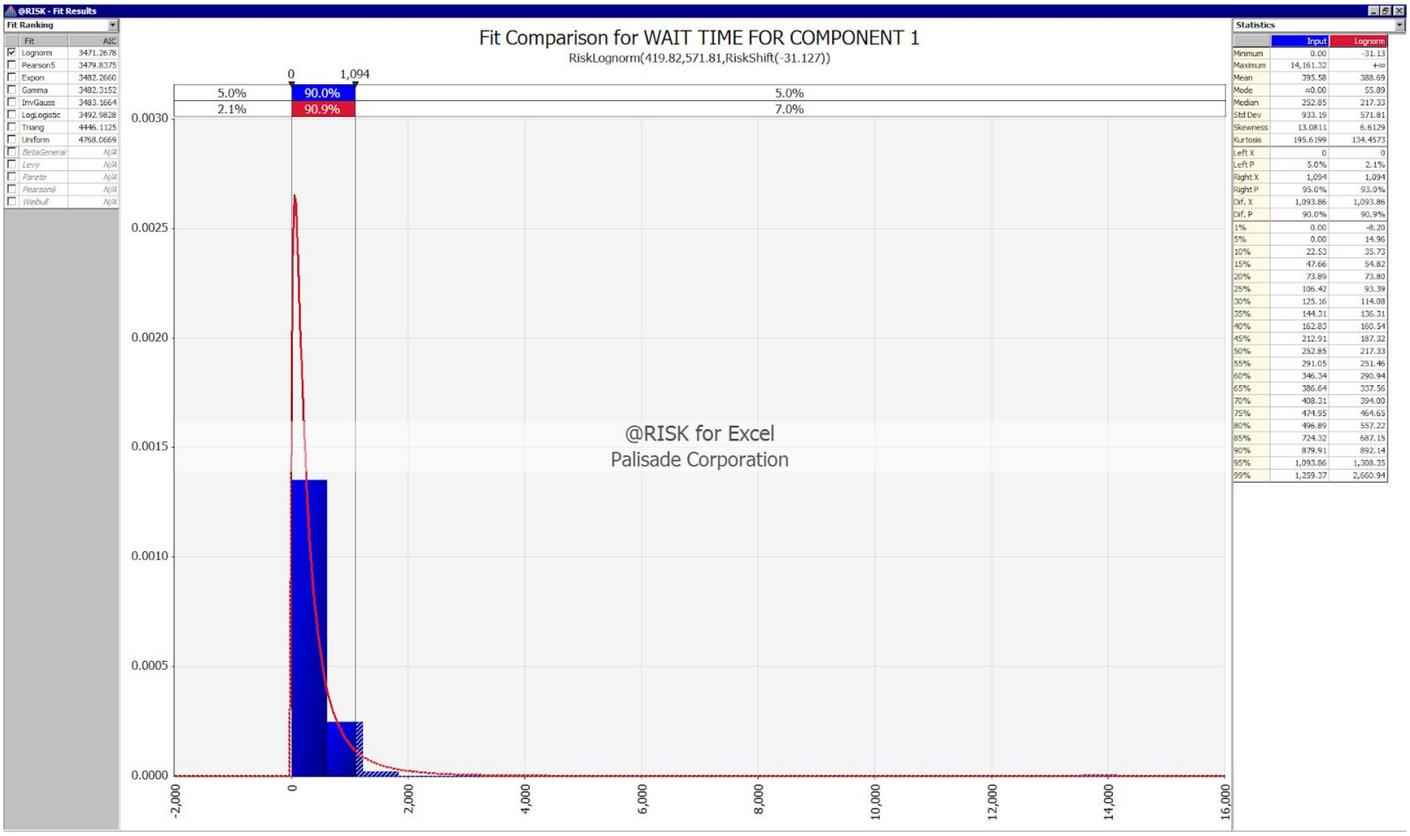

Figure 4 - Distribution for wait time of component 1

The mean for the wait time is 395.98 minutes, the standard deviation is 933.19, and group fitted a Lognormal (419.82, 571.81, shift(-31.127)) distribution to it.

WAIT TIME OF COMPONENT 2

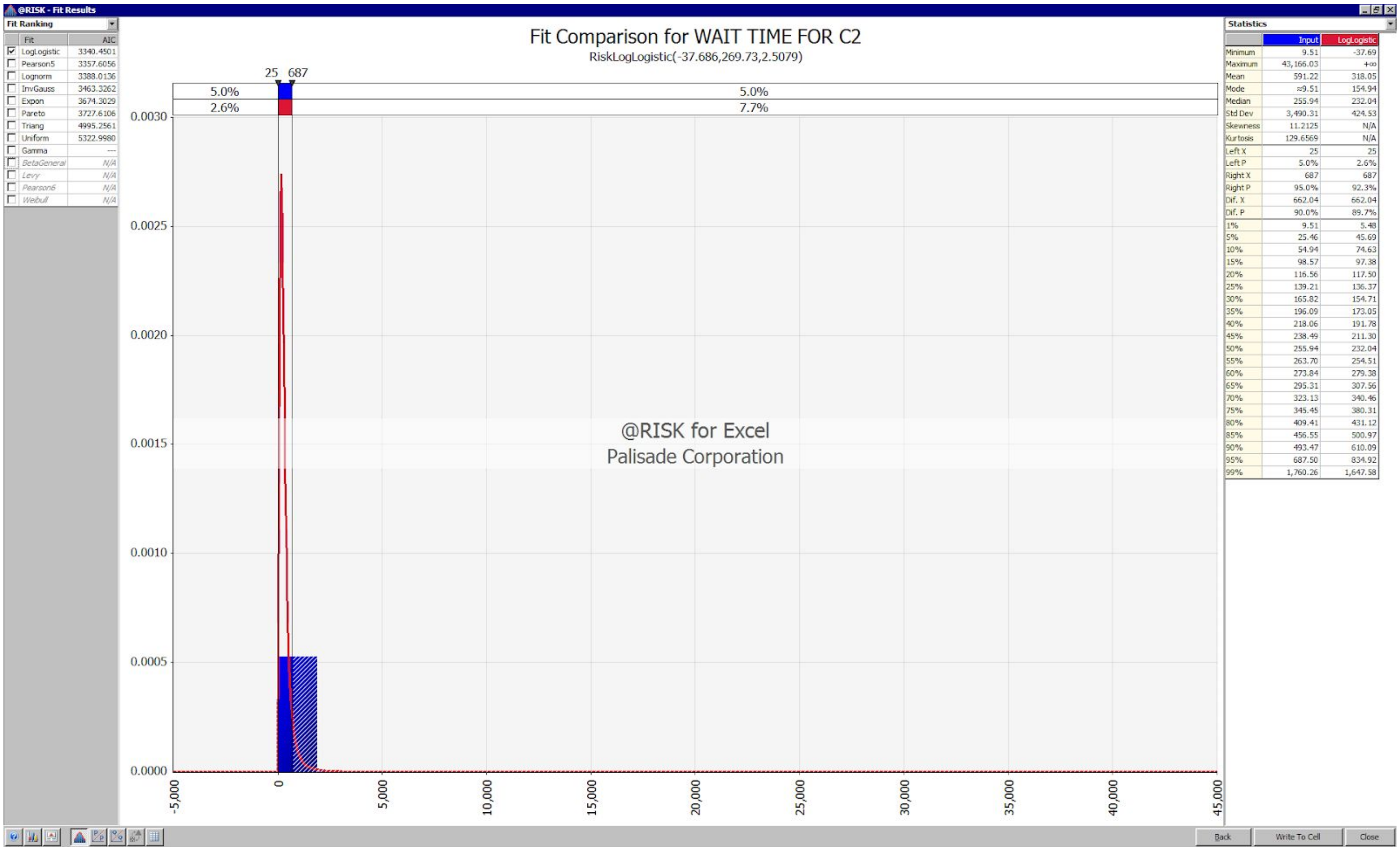

Figure 5 - Distribution for wait time of component 2

The mean for the wait time is 591.22 minutes, the standard deviation is 3490.31, and group fitted a LogLogistic (-37.686,259.73, 2.5079) distribution to it.

WAIT TIME OF COMPONENT 3

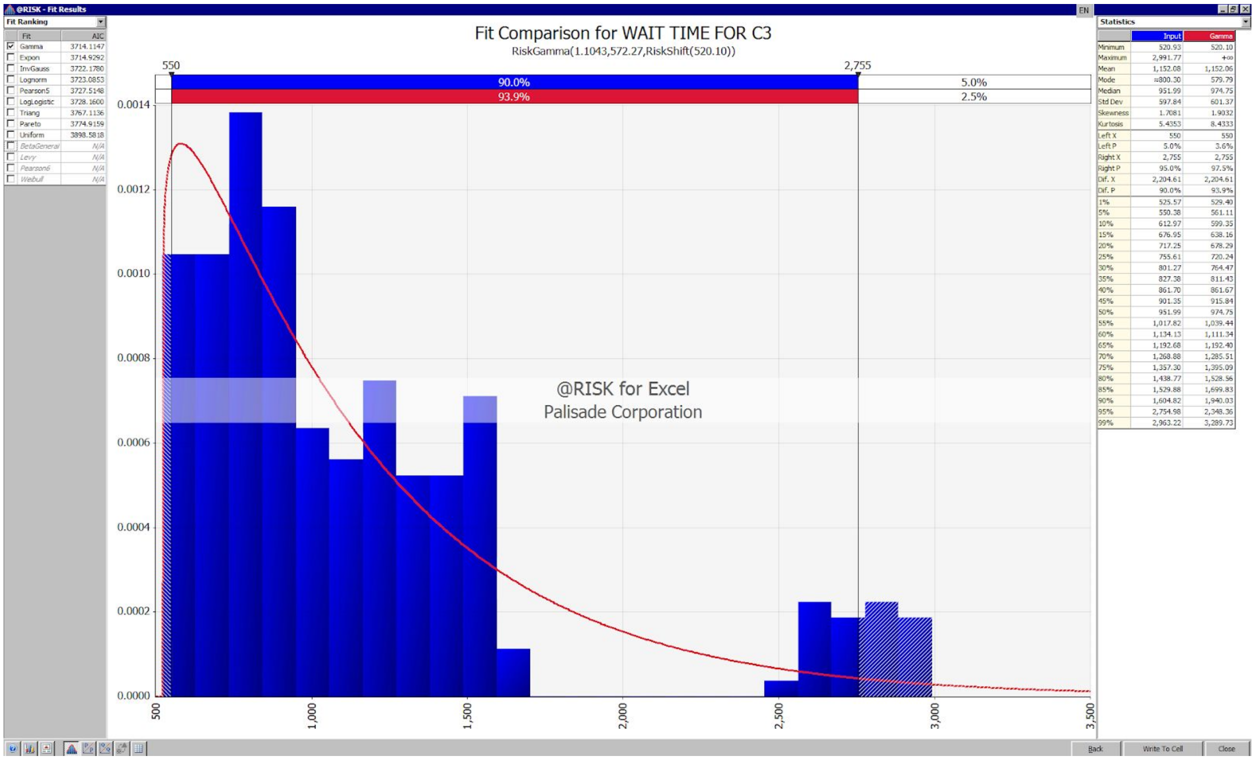

Figure 6 - Distribution for wait time of component 3

The mean for the wait time is 1152.08 minutes, the standard deviation is 597.84, and group fitted a Gamma (1.1043, 572.27, shift(520.1)) distribution to it.

WEIGHT OF FINAL PRODUCT INCLUDING PACKAGING

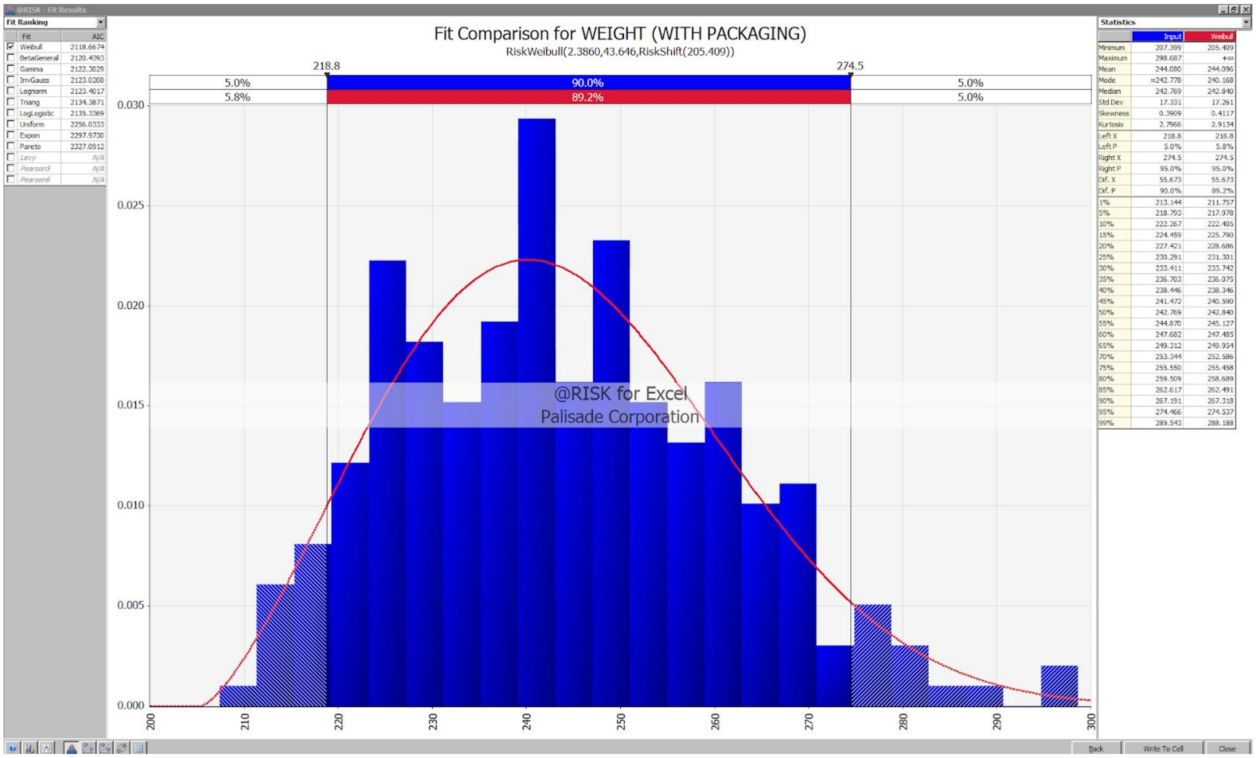

Figure 6 - Distribution for weight (everything including packaging) given in grams.

The mean for the wait time is 244.08 minutes, the standard deviation is 17.331, and group fitted a Weibull (2.386, 43.646, shift(205.409)) distribution to it.

MACHINE UTILIZATION

Machine 1: 64.19%
Machine 2: 65.06%
Machine 3: 47.39%
Assembly 1: 27.55%
Assembly 2: 19.71%
Assembly 3: 27.17%

TOTAL PRODUCTION IN 5 DAY WEEK:

250 items