Optimizing SM Paints Plant Operations Report

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Abstract

Through our analysis and simulation, we were able to determine that the most cost effective solution to meet SM Paints' objective of fulfilling 98% of orders within a three day working period is to add an additional quart line. This adjustment allowed us to achieve a 99.74% on-time fulfillment rate while also significantly reducing the quart line utilization by 15.39%. In order to determine this, we built an Arena simulation model to replicate the facility's production processes, accounting for processing times, variability in order sizes, and resource constraints. We also tested various scenarios such as adding shifts, tanks, and fill lines, to evaluate their impact on performance and cost. Using the results of these simulations, we concluded that the filling process with quart lines had the greatest effect on meeting the delivery target.

Introduction

SM Paints has been producing a line of paints at different production facilities across the US. With their current production setup, they are unable to satisfy their three day delivery requirement of 98% of orders being completed on time. Our team has analyzed the system of one manufacturing facility and has come up with a recommendation to improve production and meet this requirement. We considered a set of upgrades to the system and tested them in an Arena model. Our main metrics for improvement were the cost of the upgrade, which we wanted to minimize, and the percent of orders on time, which we wanted to be above 98%. The current production that SM Paints runs yields a score of 69.64% of orders on time.

Methodology

To begin this study, we modeled the existing production setup in Arena. We simulated production of paint for 30 replications of 65 days (3 of the days as a warm up period), and 24 hours per day. A three day warm up period is sufficient to allow initial orders to flow through the system, populate queues, and reach steady-state, thereby eliminating start up bias and ensuring accurate performance metrics.We then took the data from this run, including the percentage of orders on time, as well as each machine's utilization rate, to begin to decide which upgrade to recommend.

We tested each possible upgrade option in our model, regardless of price. We wanted to determine if any would by themselves increase the percent on time to at least 98%. We ran each new simulation for 30 replications to ensure accurate results. After testing each individual machine upgrade, we found that only one yielded an order on time rate of at least 98%. This upgrade was to add a Quart Fill line.

Next, we considered the cost of each alternative. We looked at all upgrades that cost less than the quart fill line addition and compared them to statistically prove that the quart line was the best option. We took the statistics on percent of orders on time for 30 replications of each, as well as the quart fill line statistics and performed a statistical analysis. We performed a one way ANOVA test on the means of percent orders on time based on the upgrade, to statistically prove that not all means were equal. We also utilized a Tukey

Pairwise comparison to determine which upgrade was significantly better than the rest. We accumulated all of the data from these tests and analyzed it to determine our final recommendation for SM Paints.

Results

The results from our Arena simulation demonstrated that with an additional quart fill line across 30 replications, it achieved an average on time fulfillment rate of 99.74% with a half width of 0.177%. The results of the one-way ANOVA test (Figure 1) yielded a p-value of <0.000, meaning we reject the null hypothesis and indicate that there is a statistically significant difference between the mean percents on time. According to the Tukey Comparison (Figure 2), the quart line was the only addition in Group A with a mean on-time rate of 99.74%, while all other options (MGS, BL, M and G, HT8) were in Group B with lower mean fulfillment rates ranging from 64.66% to 69.64%. Furthermore, the interval plot (Figure 4) points out that the confidence interval for the quart fill line's performance lies entirely above all the other options and the 98% target.

Discussion

All of our results point to the addition of a quart fill line. Our ANOVA shows that at least one upgrade choice yields different percent on time results than the others, and our Tukey comparisons cement that it is the addition of the quart fill line.

In order to ensure we provide SM Paints with the correct recommendations, we performed a sensitivity analysis on the arrival rate of orders ranging from an average of 20 to 26 per day. Below is our analysis and recommendation for each iteration:

- Poisson 20: We are 95% confident that if the demand drops to 20 units per day, the percentage of paint completed on time is between 99.80% and 100.00 %. This implies that no changes to the operation need to be made, therefore our recommendation would be to do nothing.
- Poisson 21: We are 95% confident that if the demand drops to 21 units per day, the percentage of paint completed on time is between 97.83% and 99.26%. This implies that no changes to the operation need to be made, therefore our recommendation would be to do nothing. The bottom portion of our confidence interval is below the 98% threshold, but spending the $1,200,000 on a quart filler would not make monetary sense as the loss from orders being late wouldn't outweigh the cost of adding the quart filler.
- Poisson 22: If the demand drops to 22 units per day, the company would need to purchase another quart filler, in order to meet the need of 98% of orders completed on time. After testing all other cheaper options, like the addition of a bucket filler or a mix and grind machine, the quart filler was the only change that reached the need of at least 98% of orders completed on time. We are 95% confident that the percentage of units on time with the addition of a quart filler would be between 99.68% and 99.98%. Therefore, our recommendation is for the company to purchase a quart filler.

Poisson 24, 25, 26 Methodology Explanation

In some cases, the on time percentage was greater than or equal to 98%, but the half-width was large enough to bring the lower-bound of the 95% confidence interval below 98%. We are calculating the expected profit loss in 3 different scenarios: worst-case, average, and best-case. These monetary tests are done by taking the average batch size of SM Paints, average price per gallon of paint in the paint industry, and an average profit margin of 3 different real-world coating suppliers (Axalta, Sherwin-Williams, and RPM). With this calculation, we can determine if investing in another piece of equipment is monetarily beneficial. In each test, we determine which option is cheapest for both raising the on time percent and lowering the half-width, by using a lowest-cost first search starting with the Mix and Grind Tank ($600k). Then we compare the price of that upgrade choice with the change in expected profit loss it would provide (expected profit loss without upgrading - expected profit loss with upgrade). If the price is less than the increase in profit, it makes the upgrade choice worthwhile (monetarily).

Assumptions

- Each test is independent from each other: buy 2 extra quart fillers means buy 2 extra from the baseline model (70% on time with 4 quart fillers).
- These calculations are testing to see if profit-increase within 1 year is covering the investment cost, but these machines likely have a useful life of more than one year. Therefore making additional investment more worthwhile.
- If an order is late, SM Paints receives no revenue.

Poisson 24

With one additional quart filler we are 95% confident that the percentage of paint completed on time is between 96.43% and 99.76%. Using our methodology from above, we tested to see if a second additional quart filler was worth it: For the worst case half-width percentages, as long as the average price of paint is above $7.60 per gallon the second quart filler is worth it. Under average half-width percentages, as long as the average price of paint is above $11.10 per gallon the second quart filler is worth it. Under the highest half-width percentages, the average price of paint needs to be $60 per gallon or above. Depending on the cost of paint per gallon, our recommendation would change, however through our research we found the average price of paint ranges between $30 and $80, meaning we would recommend that SM Paints should purchase two quart fillers.

Poisson 25

With two additional quart fillers we are 95% confident that the percentage of paint completed on time is between 95.84% and 100%. We tested to see if additional investment to raise the lower-bound was worthwhile; we found that the gallon filler was the cheapest option that raised percent on time (95% interval of 99.36% - 100%). Using our methodology from above, we tested to see if buying an extra gallon filler was worth it: For the worst case half-width percentages, as long as the average price of paint is above $8.60 per gallon the gallon filler is worth it. Under average half-width percentages, as long as the average price of

paint is above $19.10 per gallon the gallon filler is worth it. Under the highest half-width percentages, the extra gallon filler is not worth it (the upper half 95% interval of 2 quart fillers is 100%). Depending on the cost of paint per gallon, our recommendation would change, however through our research we found the average price of paint ranges between $30 and $80, meaning we would recommend that SM Paints should purchase the extra gallon filler on top of 2 extra quart fillers.

Poisson 26

With two additional quart fillers and a gallon filler we are 95% confident that the percentage of paint completed on time is between 96.46% and 100%. We tested to see if additional investment to raise the lower-bound was worthwhile; we found that the 20,000 gallon hold tank was the cheapest option that raised percent on time (100% with 0% half-width). Using our methodology from above, we tested to see if buying an extra 20,000 gallon hold tank was worth it: This round of testing was more complicated, due to the fact that there was 0% variability from 100% coverage. We used the average variability (1.77%) that 2 quart fillers and 1 gallon filler created and calculated that if the price is above $25.85/gallon the profit loss equals $4,103,522.54. This means that if the average price SM Paints charges is ~$25.85 or above, the extra 20k gallon hold tank is worthwhile. Depending on the cost of paint per gallon, our recommendation would change, however through our research we found the average price of paint ranges between $30 and $80, meaning we would recommend that SM Paints should purchase the extra gallon filler and 20,000 gallon hold tank on top of 2 extra quart fillers.

Conclusion

The primary objective of this project was to determine the most cost effective upgrade to allow SM Paints to fulfill at least 98% of customer orders in a three day period. This objective was achieved and the optimal solution was to add an additional quart fill line to the system. This upgrade consistently achieved an average on-time fulfillment rate of 99.74%. We made several assumptions in developing these results, including that the production process remained consistent regardless of the changes we tested and that demand would stay constant throughout the simulation. This allowed us to conduct a one-way ANOVA test and Tukey comparison test to determine if any of the changes were statistically significant, and the analysis confirmed that the quart line was the only statistically significant upgrade that improved the percentage of on-time orders fulfilled.

Appendix

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Upgrade	4	2.578	0.64456	16.84	0.000
Error	145	5.549	0.03827		
Total	149	8.128			

Figure 1: One Way ANOVA Test Results.

Grouping Information Using the Tukey Method and 95% Confidence

Upgrade	N	Mean	Grouping
QL	30	0.997423	A
MGS	30	0.6964	B
BL	30	0.6964	B
M and G	30	0.6554	B
HT8	30	0.6466	B

Means that do not share a letter are significantly different.

Figure 2: Tukey Comparison Mean Grouping (MGS = Mix and Grind Shift, BL = Bucket Line, M and G = Mix and Grind Tank, HT8 = 8000 Gallon Hold Tank).

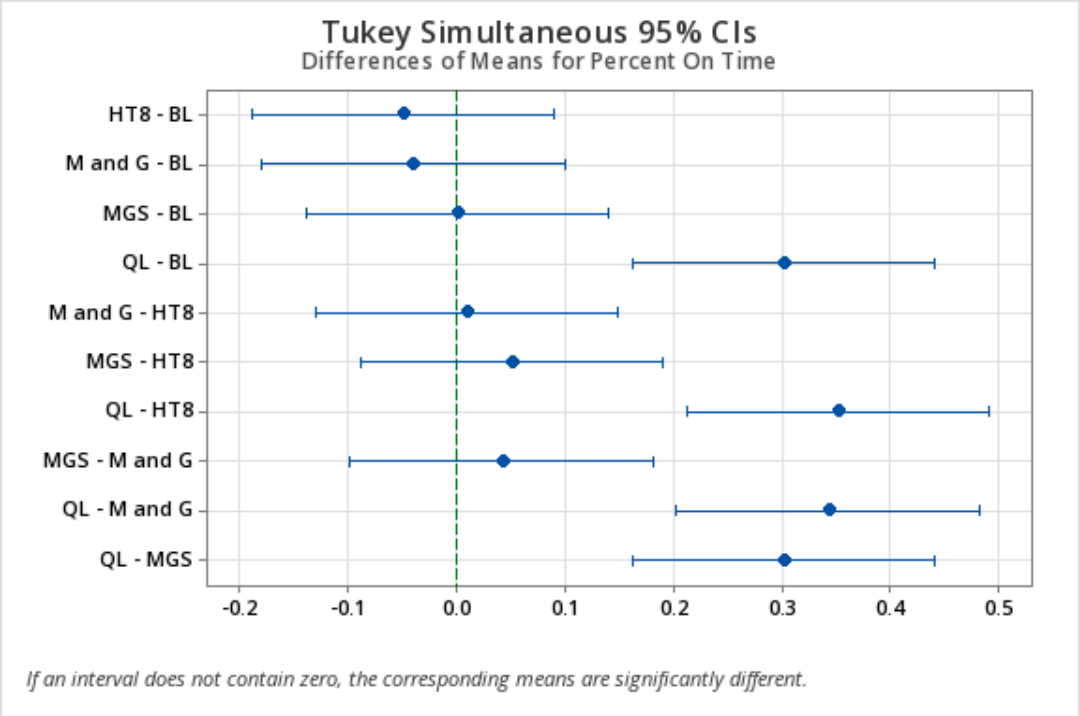

Figure 3: Tukey Comparison for Different Upgrade Choices.

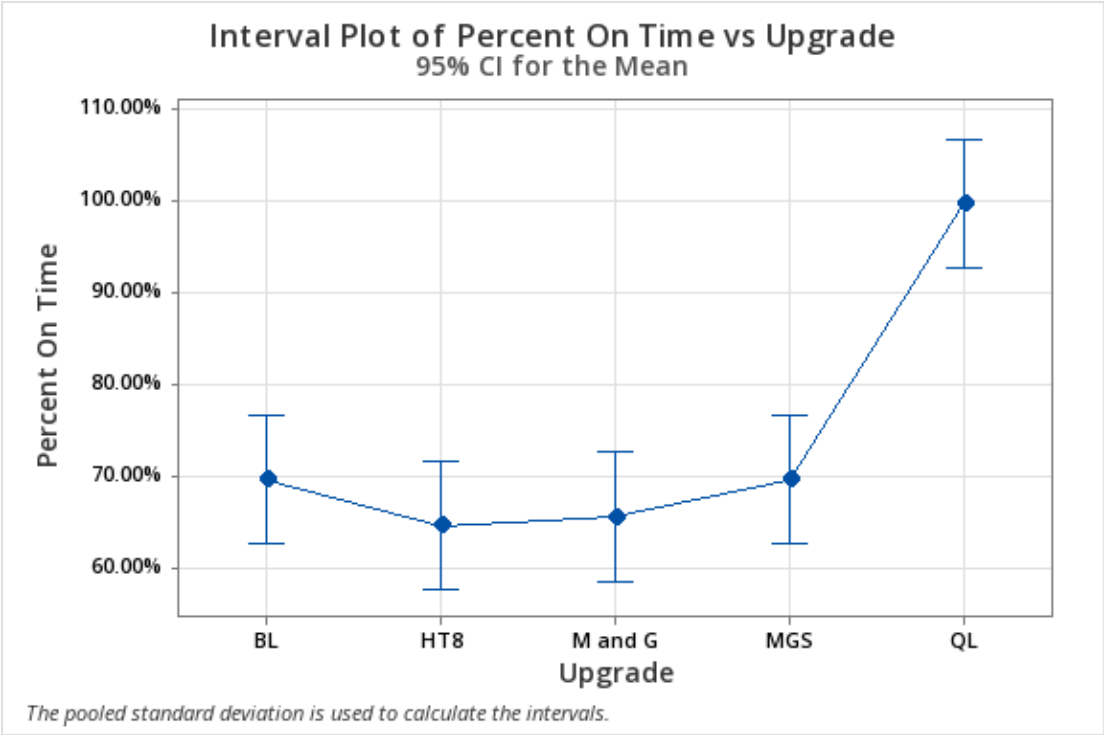

Figure 4: Interval Plot of Percent Orders On Time vs Upgrade Choice.