Managing Supply Uncertainty in the Poultry Supply Chain

By: William Gordon
Thesis Advisor: Dr. Asad Ata

Summary: Because of production process variability, it is difficult for CKN Corporation executives to estimate the total time to complete a day's orders. As CKN Corporation scales up in size, it becomes even more critical to have tight control of the production process. This research looks into the sources of variability and investigates strategies to reduce overall process variability. Through a discrete event simulation, this research analyzes the effects of improved control on chicken size, more regular live-chicken deliveries, and the elimination of perceived bottlenecks.

William holds a Bachelor of Science, Industrial Engineering and Operations Research from the University of California, Berkeley and is a Six Sigma Black Belt. While an Operations Engineer at Pacific Gas & Electric Company, William created a range of business intelligence and automation software packages and led several successful business process improvement initiatives. Following his education that Malaysia Institute for Supply Chain Innovation, William will work in the transportation group at Amazon.com as a Senior Program Manager.

KEY INSIGHTS

1. The variability in the time to process a day's orders can be traced to the distribution of live chicken arrival times.

2. Perfectly uniform truck arrivals eliminated nearly all variability in the total time to process a day's orders. Delivery windows as wide as twenty minutes reduced variability by approximately 50%.

3. Completely eliminating the halal slaughtering method had no statistically significant effect on the total time to process a day's orders nor the overall process variability. Eliminating the halal slaughtering method would not reduce process variability or processing time in any significant way.

Overview of CKN Corporation

CKN Corporation is a large poultry processor in Malaysia. The parent company has a highly vertically integrated supply chain for flour, feed, and poultry. Their supply chain only stops short of growing the grain and breeder chicken upstream and selling to the end-consumer downstream. The company controls all steps in-between. CKN Corporation also owns everything from the port that receives grain from North America through the flour and feed mill, breeding chickens, hatcheries, farms, processing plants, transportation and distribution channels. The feed mill provides food for their chicken farming operations.

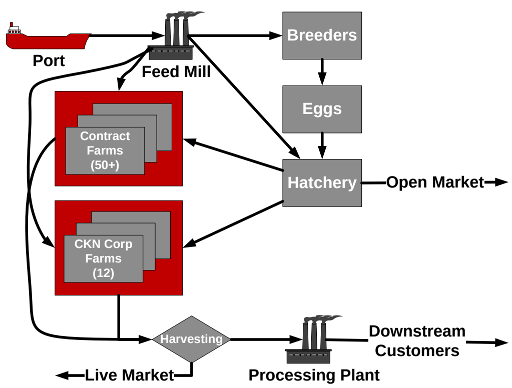

Figure 1: CKN Corporation Internal Supply Chain

Source: Author

In those operations CKN Corporation owns the breeding chickens, hatcheries, farms, processing plant, and all transportation assets. The chicken farming and processing is only a small part of the parent-company's business. CKN Corporation's sales span across many South East Asian countries and the corporation has plans to substantially expand its market share. It is planning to increase its production of processed poultry nearly five-fold.

In light of CKN Corporation's expansion plans, it is necessary for CKN Corporation to exert tighter control on the total processing time at the chicken processing facility. The processing plant creates the vast majority of CKN Corporation's salable product. Its mission is to fulfill customer orders at the lowest cost possible while meeting the necessary quality guidelines. The processing plant has several tasks to support this goal. These tasks are broadly overviewed in Figure 2.

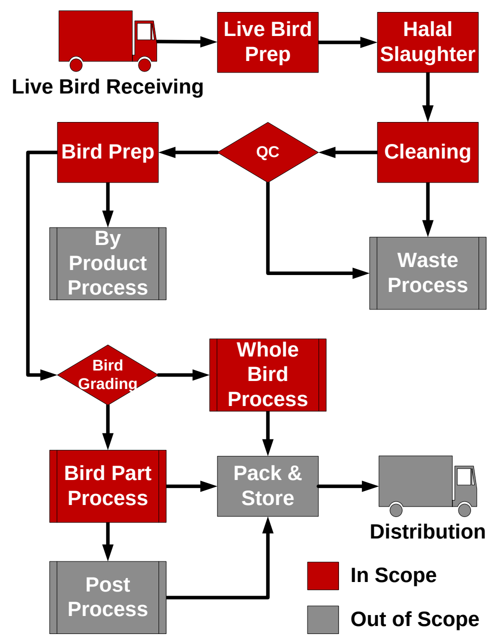

Figure 2: Summary of In-Scope and Out-of-Scope Processing Plant Activities

Source: Author

Simulation Model

The simulation model was built using SIGMA simulation software. The model contains all necessary process steps to simulate the poultry processing plant. For the purposes of the simulation, the production process was reduced to steps that had a quality control checkpoint, steps that had a process queue, and steps that involved rerouting of chickens or parts.

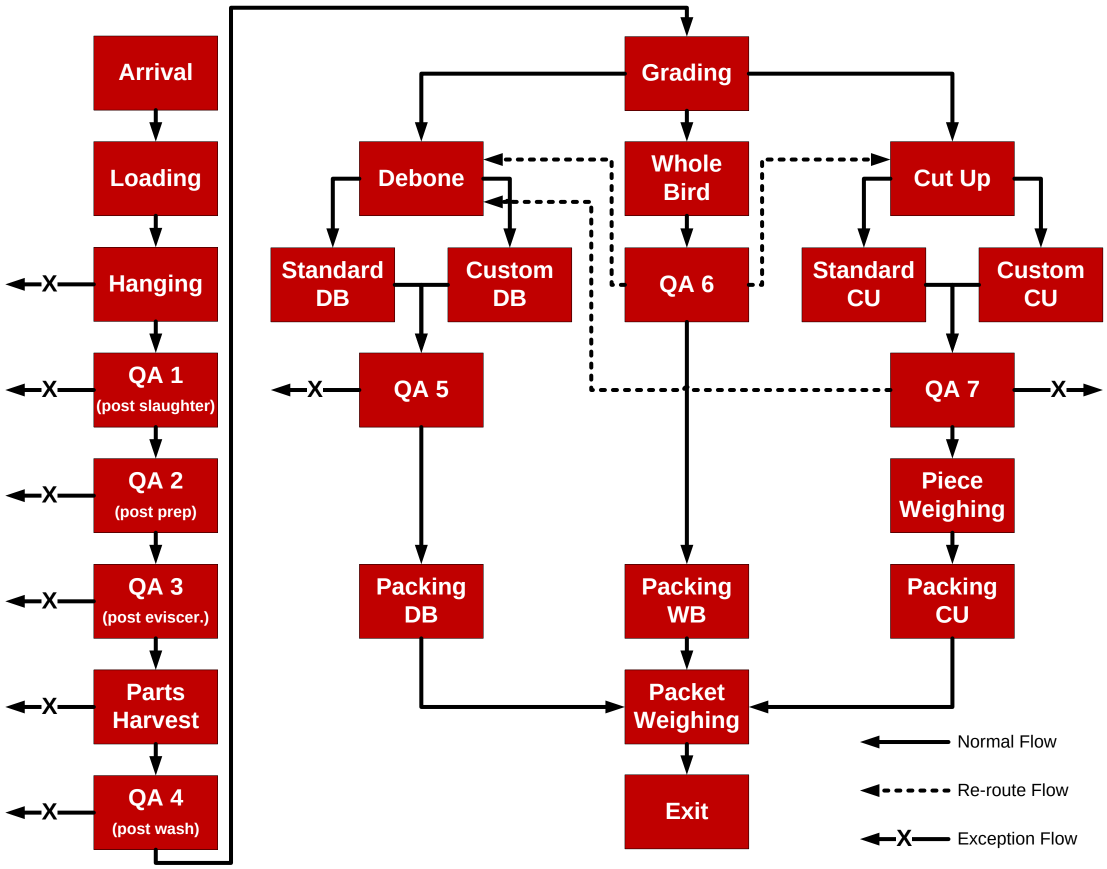

Figure 3: Simplified Process Flow Diagram Used for Simulation Model
Source: Author

The simulation model was used to test four different scenarios:

1. Baseline production (random truck arrivals and regular chicken size distribution)
2. Scheduled deliveries (evenly spaced truck arrivals and regular chicken size distribution)
3. Narrow chicken size (random truck arrivals and narrow chicken size distribution)
4. Scheduled deliveries and narrow chicken sizes (evenly spaced truck arrivals and narrow chicken size distribution)

In addition to the four scenarios listed above, a sensitivity analysis determined the widest possible delivery window that would still reduce overall process variability. Also, a simulation analyzed if removing the manual halal slaughter method would significantly change the total processing time or variability. Each scenario will consist of fifteen simulations, each spanning a full processing day. At the end of each simulation data is collected to measure the total time required to process all chickens and the total number of rejected chickens and chicken parts. These variables are compared across the scenarios. For the sensitivity analysis only five iterations of the simulation are run.

Hypothesis Testing and Scenario Detail

This research simulates four different scenarios to measure the process variability under different conditions. The scenarios are briefly summarized in **Error! Reference source not found.**Table 1 and explained in more detail below.

Scenario	Arrival Time	Size	H Tests
I	Poisson $\mu = 20$	1.5 to 3	-
II	Constant t = 20	1.5 to 3	H_0
III	Poisson $\mu = 20$	1.8 to 2.6	H_1
IV	Constant t = 20	1.8 to 2.6	H_2, H_3, H_4

Table 1: Summary of Simulation Scenarios
Source: Author

Scenario I: Baseline
The scenario will be used to validate the simulation model and be used as a reference for subsequent simulation runs. After running this simulation, the data to measure variability will be collected and used as a baseline against the subsequent scenarios.
Scenario II: Delivery Scheduling
This scenario is identical to the baseline scenario, except the trucks will be arriving at a constant, deterministic rate instead of a stochastic rate.
Scenario III: Pre-Processing Quality Control
This scenario is identical to the baseline scenario, except the chickens follow a much narrower distribution.
Scenario IV: Delivery Scheduling with Pre-Processing Quality Control
This scenario is runs both of the change conditions at the same time. This will be used to compare the output against not only the baseline scenario, but also against the two other scenarios.

Hypothesis H_0: A constant delivery inter-arrival rate will reduce overall process variability.
Hypothesis H_1: Reduced chicken size variability will reduce overall process variability.
Hypothesis H_2: A constant delivery inter-arrival rate and reduced chicken size variability will reduce overall process variability.
Hypothesis H_3: A constant delivery inter-arrival rate and reduced chicken size variability will have less overall process variability than a process with only constant delivery inter-arrival rate.
Hypothesis H_4: A constant delivery inter-arrival rate and reduced chicken size variability will have less overall process variability than a process with only and reduced chicken size variability.

Results and Analysis
There are two major parameters measured for each scenario: the total processing time and the number of rejected chickens or parts for each run. These statistics were collected for each simulation for each scenario. A plot of the total processing times is shown in Figure 4.

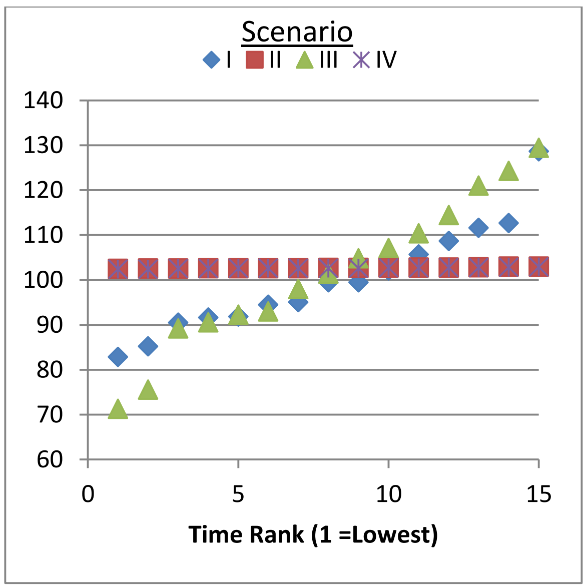

Figure 4: Total Chicken Processing Time
Source: Author
Notes: Y-axis 100 = Average time for scenario I.

In Figure 4, the time is compared against the average processing time for the baseline scenario. These values are scaled such that the average processing time for the baseline scenario is 100. In these simulations, the total number of rejected chickens and parts did not deviate in any meaningful way. The percentages of rejected birds and parts ranged from 10.7-10.8%. One can observe visually, however, that there were substantial differences in variability due to the presence or absence of delivery scheduling. Total processing time varied by over 50% for any process without delivery scheduling compared to variation of less than 1% for processes that included delivery scheduling. A one-sided t-test was performed on the data to compare the differences between total number of rejected birds and total processing time. No significant difference was found between the four scenarios. The significance tests on the variances, however, confirmed three of the five hypotheses.

Hypothesis	P-Value
H_0	.0000
H_1	.2164
H_2	.0000
H_3	.7680
H_4	.0000

Table 2: Hypothesis Test Results
Source: Author

The variance appears to depend greatly on the presence of delivery scheduling. Based on the above results, there is strong evidence for hypotheses 0, 2, and 4. The combined results suggest that Delivery Scheduling is the most effective means to reduce overall process variability.

Sensitivity Analysis

Many of the processing speeds and time delays were approximations, so there are many different sensitivity analyses that can be performed on this simulation. This research will focus on one particular analysis: the variation in truck deliveries. The sensitivity analysis will model different scenarios with respect to a mean delay of twenty minutes between truck arrivals. The baseline scenario has truck inter-arrival times modeled with an exponential r.v. In this sensitivity analysis, the inter-arrival times will be modeled with a uniform r.v. The first scenario will have a 30 minute window with mean time equal to twenty minutes (U[5,35]). There will be five simulations and the variance will be compared to the variance in the Baseline scenario. If the variance is not significantly different, the window will be reduced by ten minutes (i.e. U[10,30]). If the variance is significantly different, the window will be increased by ten minutes (i.e.[0,40]). This process will be repeated until the largest possible window with a statistically indistinguishable variance is discovered. If the window needs to be repeatedly increased, the simulation will switch to a triangle distribution with mode equal to 20. Variances will be compared using an F-Test. An additional scenario will be run for the elimination of the halal slaughter method.

Scenario	P-Value (F-test)
30 minute window	.2515
20 minute window	.0637
10 minute window	.0098
No halal method	.8759

Table 3: Sensitivity Analysis Results
Source: Author
Notes: F-test performed against baseline scenario I.

During the actual sensitivity analysis, the 30 minute window was not significantly different. The twenty minute window was significant at the .10 level. The ten minute window was significant at the .01 level. Therefore, if CKN Corporation can schedule truck deliveries down to a ten to twenty minute window, the company will see a significant reduction in its overall chicken processing time variability. The halal slaughter method did not have a significantly different variance from the baseline scenario. The overall processing time was not changed in any significant way by removing the halal slaughter step.

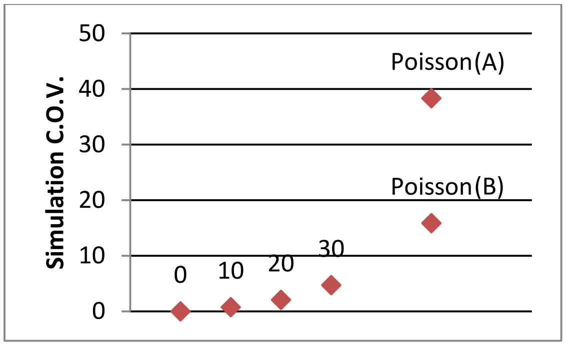

Figure 5: Delivery Window vs. Coefficient of Variation
Source: Author
Notes: Each point represents a delivery window size, e.g. 0 represents perfect delivery and 10 represents a ten minute delivery window. Poisson(A) represents automated slaughter (i.e. non-halal) and Poisson(B) represents manual slaughter (i.e. halal).

Recommendations

Based on the results of the simulation, it appears a targeted effort to improve the delivery truck delivery schedule would greatly reduce the overall variability of the total time required to process chickens. Even scheduling the deliveries to a ten to twenty minute window will still provide substantial reductions in overall variability. CKN Corporation could dedicate a staff member to coordinating the dispatch and arrival of delivery trucks arriving to the processing plant—carefully measuring the time required to travel to company and contract farms, the time required to collect chickens, and the time required to return to the processing plant. Traffic and congestion conditions may result in different travel times to and from the farms—additionally, there may be wide seasonal variation. New research could be devoted to determining best practices for transporting chickens to ensure not only predictable travel times, but also for reducing the total number of DOA chickens. The halal slaughter step is not a significant process bottleneck and removing that step would neither reduce the total processing time nor reduce the total variability in the production process. Although the simulation did not show significant reductions in variability or in total rejects as a result of greater control of chicken size, it may still be desirable to impose stricter standards or adopt technology to help control the size of the chickens. First, although the simulation did not show a significant reduction in total rejections, there was a small decrease in the number of rejects due to bursting. This decrease may be greater in real life because of the uncertainty in today's true chicken size distribution. Secondly, there was no element in the chicken size on quality control on any processing step except for after evisceration. There may be other effects that contribute to lower defects resulting from more standardized chickens. For instance, if workers become accustomed to working with more standardized chicken sizes, they may make fewer mistakes. Such effects were not modeled in the simulation. Finally, a narrower band of chicken sizes will help CKN Corporation make better predictions of what kinds of products they can sell to their customers. This benefit was not captured in this research but may offer significant value.

Future Research

This research provides a foundation to perform additional analysis into methods to improve overall process operations at a meat processing plant. For CKN Corp, specifically, this research can be extended to include more elements of its supply chain and include more detail on its processing plant operations. This research found that scheduling chicken deliveries is a highly effective method to reduce overall process variability. However, there is still additional research that can be performed. The potential areas for future research can be broken into several categories: Primary processing activities, secondary processing activities, pre-processing activities, and post-processing activities.

All further processing activities were intentionally excluded from this research in order to simplify the simulation and documentation effort required. The further processing activities provide significant value to CKN Corporation and should be documented further and strategies to improve their yield and profitability should be investigated.

Additionally, it may be useful to allocate some workers as “flexible” workers who cross-trained in multiple activities. Currently, workers specialize in a certain activity, but as a truck is unloaded, they may sit idle for extended periods if they have no work in their queue. Future research could look into policies to allocate these workers effectively.

The distributions of demand have been ignored from this research. However, there is noted seasonality in the demand distribution and should be accounted for. This makes for an especially interesting topic when combined with the ability to store frozen chicken to fulfill some customer orders. This would allow CKN Corporation to smooth its demands on the processing plant and potentially minimize its flexible staff. Additionally, the same-day demand for chicken is not well-known and orders can be created late into the same day. This can force CKN Corporation to source chickens from contract farms or to harvest chickens before they have reached an age of 40 days, causing the average size to be sub-optimal. CKN Corporation covers this variability by ordering extra chickens every day. Determining the proper size of this buffer could be solved using the newsvendor model.

Currently, CKN Corporation has a standard inventory policy for all of its products. The storage of its products should be analyzed to determine proper stock keeping levels for its products. Furthermore, some of its stored material is thawed and used to fulfill some customer orders. This dynamic that makes stored product available for both immediate sale and value-added processing makes for interesting potential research.

Fortunately, the SIGMA model is flexible enough to be able to account for many of the above suggestions for future research, particularly queue sizes, process variability, and including additional processing steps or paths. This model should provide a solid foundation for future work in this area.

Key Takeaways

The narrow chicken size distribution had no significant impact on total process variability. However, the delivery scheduling had a significant impact. Live chicken delivery windows as wide as twenty minutes cut overall process variability in half compared to the Poisson distribution baseline scenario.

Furthermore, the simulation found no statistically significant impact on the total processing time or process variability from the manual halal slaughtering step. This process did not prove to be a significant bottleneck to the overall production process.