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CONFIDENT DECISION MAKING AND IMPROVED THROUGHPUT FOR CEREAL MANUFACTURING WITH SIMULATION

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ABSTRACT

In 1999, Kellogg Company needed to rationalize its area manufacturing capacity. A significant portion of the production was moved between Kellogg manufacturing plants. Simulation played an important role in two facets of this project. First, it helped determine if the proposed engineering changes would pick up the slack in production lost due to idling of assets. Second, simulation was used to develop line management setpoints for increasing the output from the installed capacity.

1 PROJECT BACKGROUND

The project objective was to identify a production scheme that would result in maximum throughput. A simulation model was created to reflect the finished product (A) and finished product (B) production at Kellogg's Plant (2) and Plant (3).

The model reflected the processing and movement of food, beginning at the cookers and ending at the packaging lines. It was then was used to determine the effects that cook cycle, oven rate, and surge bin trigger levels have on throughput.

2 SYSTEM DESCRIPTION

The model included the processing at the cooking vessels, the flow through the apron feeder, the drying conveyor, the temper surge bin, the mills, the ovens, the coater, the surge buffers and tanks before packaging, and the packaging lines.

2.1 Cooking Vessels and Hot Temper Surge

For the cooking vessels, the model included a cook cycle time, which reflected the interval between cook batches unloading to the apron feeder and the percentage of missed cook batches. The cookers alternate dropping off their loads into the apron feeder. There can be up to 12 possible cook cycle steps in the model. Changes in the cook cycle are triggered by changes in the amount of hot temper surge bin content. The setting of the cook cycle trigger points in the hot temper surge bin represented an important area for experimentation.

For the apron feeder, the model reflected a dwell time and an output rate to the dryer. The apron feeder output rate is controlled by the cook cycle and changes when the cook cycle changes. From the apron feeder, cooked product is fed to the drying conveyor.

For the drying conveyor, the model reflected a transfer time and an output rate of cooked product to the hot temper surge bin.

At the hot temper surge bin, the model reflected a dwell time and output rate to the mill deck. The content level of the hot temper surge bin can trigger changes in the cook cycle. From the hot temper surge bin, cooked and dried cooked product is fed to the mills.

2.2 Mills and Ovens

Cooked product from the hot temper surge bin flows through the mills becoming flakes. The flakes are then conveyed to the ovens for toasting. If there is more cooked product feeding to the mills than the ovens can toast, a mill overflow will return the un-milled cooked product to the hot temper surge bin. Those flakes that are toasted are sent either to a packaging line, finished food surge bin, or to the coater to become finished product (B). The direction taken is plant and schedule dependent.

An important scheduling distinction is whether the model being run represents a finished product (A) or finished product (B) priority.

2.2.1 Finished Product (A) Priority

If the packaging priority is for finished product (A), one of two things happens. Either all of the toasted product goes to the finished product (A) packaging lines and surge bins;

or the system minimum amount of milled product will be directed to coating to become finished product (B), with the remaining load being packaged as finished product (A).

Most schedules require finished product (B) and finished product (A) be made at the same time. If the scheduling priority is for finished product (A), and the finished product (A) finished food surge bins are filled up; the coater load will be increased. This is done to avoid decreasing the cooking cycle and reducing system output. If the finished product (B) surge bins are also full, the remaining milled product will be kept in temporary mobile storage tanks until they can be packaged on one of the packaging lines.

2.2.2 Finished Product (B) Priority

If the packaging priority is for finished product (B), then enough toasted product will be directed to the coater to maximize its utilization.

2.2.3 Oven Control

The model allows for up to 13 oven output rate settings. Changes in oven rates are triggered by either the combined finished food finished product (A) and finished product (B) surge bin levels or the cooked product level in the hot temper surge bin. The hot temper surge bin also has an established minimum and maximum level that can not be exceeded, this is included in the decision logic.

The decision logic for protecting the minimum and maximum hot temper surge bin level has two basic rules:

1) If the difference between the input rate and the current output rate of the hot temper bin results in over capacity of the bin and oven rate is decreasing, a higher oven rate will be selected. This logic prevents the hot temper surge bin from exceeding its capacity and "pushes" the product through the system to be collected either in the finished food surge bins or the mobile finished food tanks.
2) If the difference between the input rate and the current output rate of the temper bin result in the contents of the hot temper surge bin being less than the desired minimum volume, and the oven rate is increasing, a lower oven rate will be selected.

A second option for the oven rate logic was also tried initially. This option adjusted the delays between level changes rather than focusing solely on the change itself. The reasons this option was not used are discussed in the results section of this paper.

Flow charts for the oven change logic are seen in figure 1.

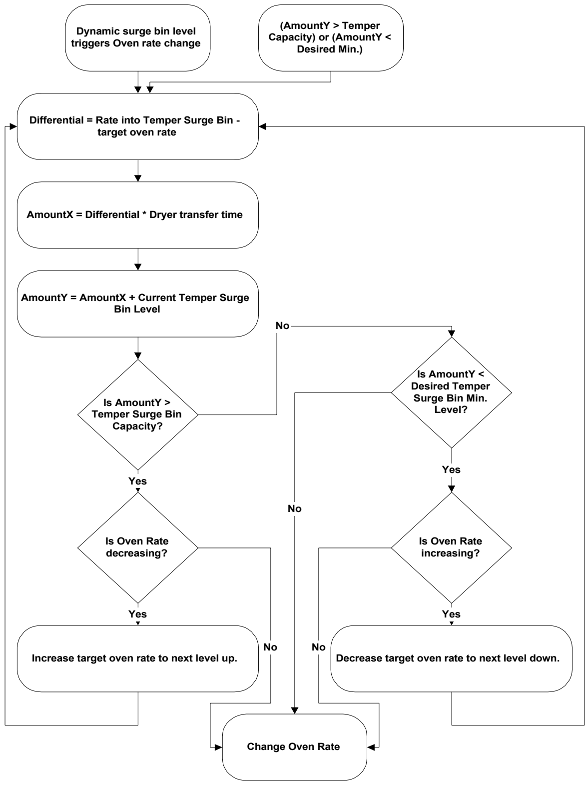

Figure 1: Flowchart for Oven Change Logic

2.3 Coater

The model reflected a coater transfer time and an output rate to packaging. The model allowed for several coater output rate settings. The coater settings used during a model run were based on whether the production schedule was finished product (A) or finished product (B) priority schedule. The finished product (B) surge bin level determines the coater rate under a finished product (B) priority schedule. If a finished product (A) priority schedule is selected, the minimum coater rate will be run unless the finished product (A) surge bin fills, then the coater rate will be increased.

Maintenance downtime of the coater was an option in the model and could be set through an input spreadsheet. After a maintenance downtime occurs, a significant amount of finished product (B) must be discarded. After coating, finished product (B) proceed to packaging or to the finished food finished product (B) surge bin & tanks.

2.4 Packaging Lines, Surge Bins, and Tanks

The model included finished product (A) packaging lines and finished product (B) packaging lines with processing times and down times. Priority between packaging lines can also be assigned through the input worksheet.

2.4.1 Plant (2) Flow

Finished product (A) is sent from the ovens to the finished product (A) surge bins over the finished product (A) packaging lines, finished product (B) is sent from the coater to the finished product (B) surge bins over the finished product (B) packaging lines. Packaging lines will draw finished product (A) or finished product (B) from these surge bins. When the surge bins are filled up, finished product (A) will be sent to finished product (A) tanks and finished product (B) will be sent to finished product (B) tanks.

Finished product (A) and finished product (B) stored in tanks are used to provide finished food to the "individual size" packaging lines. The tank discharge rates are specified in the input spreadsheet.

2.4.2 Plant (3) Flow

Finished product (A) is sent directly from the ovens to the finished product (A) packaging lines and the coater provides finished product (B) to the packaging lines. When the packaging lines are filled up, finished product (A) will be sent to the finished product (A) surge bin and finished product (B) will be sent to the finished product (B) surge bin. If the surge bins are full, finished product (A) will be sent to the finished product (A) mobile tanks and finished product (B) will be sent to the finished product (B) mobile tanks.

When a finished product (A) packaging line is available, finished product (A) will be drawn from the finished product (A) surge bin and finished product (A) tanks. Or when a finished product (B) packaging line is available, finished product (B) will be drawn from the finished product (B) surge bin and finished product (B) tanks.

3 KEY ASSUMPTIONS

The following assumptions were made to facilitate building a valid model in the most efficient manner possible:

1) None of the operations modeled stopped for lunches or breaks.
2) Downtime was only modeled at the packaging lines.
3) A gamma distribution with a shape factor of two was utilized for modeling time between failure, and a gamma distribution with a shape factor of 1.4 was utilized for modeling time to repair all packaging lines.
4) Reject points were not be modeled, since product is rejected only for quality reasons, and this model focused on issues of design capacity.
5) It was assumed that corn would be available at the cookers as needed.
6) The operations modeled ran on a 24 hours/day, 7 days/week basis.
7) For the purpose of this set of experiments, delay for oven changes was set to zero.
8) The model started with the hot temper surge bin at the desired minimum capacity.
9) The ovens started once cooked product had reached the hot temper surge bin.

4 SYSTEM PERFORMANCE MEASURES

To assist in quantifying the effect of the various experiments performed with this model, the following performance measures were available in the model output reports:

1) Average finished product (A) production rate.
2) Average finished product (B) production rate.
3) Average apron feeder output rate and content.
4) Average hot temper surge output rate and average hot temper surge content.
5) Average oven output rate.
6) Average coater output rate.
7) Average finished product (A) surge bin and finished product (B) surge bin contents.
8) Average finished product (A) tank and finished product (B) tank contents.
9) Average output rate of each packaging line.

5 EXPERIMENTATION

Experimentation with this model was focused on different line management philosophies and determining the production pattern that results in maximum throughput. The following input parameters were experimented with to support this:

1) Oven control option.
2) Number of cook cycle possibilities.
3) Trigger settings for the hot temper surge bin and cook cycle value.
4) Number of oven rate possibilities.
5) Trigger settings for the total finished food surge and oven rate value.
6) Trigger setting for the coater surge and coater rate value.

6 RESULTS

The first set of experiments was used to get a feeling for how the modeled system would perform. Different cook cycle and oven change scenarios were run for both of the oven control options. After studying these results, it was evident the oven control option that adjusted the delay between rate changes was regularly violating the minimum and maximum constraints of the temper surge bin. This wasn't acceptable and it was eliminated from the rest of the experiments.

The initial set of experiments had two basic cycle change scenarios. There was a high scenario (with seven steps for cook cycle changes and nine for oven rates) and a low scenario (with three steps for both cook cycles and oven rates). These were further broken down by making an "aggressive" and a "conservative" version of each scenario. The conservative scenarios would slow down output much sooner than in the aggressive scenarios, while the aggressive scenarios risked exceeding maximums for the various surge bins.

The aggressive scenarios in the experiments produced more finished product (A) overall. The number of cook cycles available was not a significant factor in determining system throughput. The nine aggressive oven rates scenario did produce more finished product (A) than the three rate scenario.

With the results of the first set of experiments in mind, we created a new set of experiments. This time we used only the oven control option shown in the figure 1 and we based our rates on the more aggressive scenarios. We also created a much wider variety of possible steps (two, three, five, seven, and nine for cook cycles and two, four, five, six, seven, eight, nine, eleven for oven rates).

For the final set of experiments, consistently greater system throughputs were reported when five cook cycle steps were used. However, Experiments utilizing three, seven, or nine cook cycle steps still performed well enough to meet the new demands.

The two experiments performed with two simple oven rate steps, performed the best. It would either shut the ovens off or produce as much as possible. This not the best approach to managing the production, however, because of the desire to package the cereal when it is as fresh as possible.

Beyond this, oven rate regimes with moderate (four to nine) number steps all performed adequately, with no statistically significant differences.

7 SUMMARY

This simulation model has greatly aided Kellogg Company. It proved what it set out to, which is there is enough capacity available to complete the rationalization of capacity.

The model has also helped investigate how trigger levels for the cook cycles and oven rates should be set. This information will allow Kellogg Company to increase its finished product (A) and finished product (B) manufacturing capability while curtailing expenses.

Simulation proved to be an ideal tool to investigate whether the major changes called for by the business plan could be carried out without severely hurting the production capacity.

AUTHOR BIOGRAPHIES

TRAVIS A. DAHL is a Systems Engineer for The Model Builders. He has experience successfully modeling and analyzing systems. His contributions include assisting in the design of simulation models, developing valid models, performing detailed experimentation on these systems. He has a strong interest in automating the simulation process to make developed models as easy as possible to use. He received his Bachelor of Science in Industrial Engineering from Rensselaer Polytechnic Institute. His email address is `<TravisDMB@cs.com>`.

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