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SHARED RESOURCE CAPACITY ANALYSIS IN BIOTECH MANUFACTURING

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ABSTRACT

Simulation is a relatively new tool for business process analysis in the Biotech industry. This paper discusses an application of discrete event simulation in analyzing the capacity needs of a shared resource in the manufacturing facility at Bayer Corporation's Berkeley site. The SIGMA® simulation model was used to analyze the workload patterns, run different workload scenarios, taking into consideration uncertainty and variability, and provide recommendation on a capacity increase plan. This analysis also demonstrated benefits of certain operational scheduling policies. The analysis outcome was used to determine capital investments for 2002. The paper illustrates the power of simulation tools in providing quick and robust analysis with solutions to planning problems.

1 INTRODUCTION

Bayer Corporation's Berkeley facility is the global headquarters for Bayer Biotechnology. The facility houses research as well as manufacturing operations. Currently, the manufacturing operations produce a drug (Kogenate-FS®) based on second generation recombinant DNA technology. The drug treats Hemophilia that is caused by the lack of factor eight protein. As the drug needs to be administered at regular intervals, a consistent and reliable supply is a prime objective for Bayer's Berkeley facility.

Consistency in the supply of final drug product requires consistency in the manufacturing operations as well. Resources influence the reliability of manufacturing operations, especially those shared across manufacturing stages. Capacity of these shared resources is coming under scrutiny with increasing production volumes. This paper discusses capacity analysis for one such shared resource.

2 BACKGROUND

The Berkeley site has multiple manufacturing facilities. In one particular facility, up to four distinct manufacturing areas share a common resource, called Blast Freezer. Primarily two areas shared this resource until 2002. In 2003. Two more areas were brought into service that would require these Blast Freezers. As part of planning, many resources and utilities underwent a detailed analysis to ensure adequate support for these two new areas. The primary analysis indicated Blast Freezers as a potential bottleneck and a critical step (Ryan and Gupta, 2002; Witz, 2002).

Site management needed quick and robust decision support on how to ensure adequate Blast Freezing capacity for increasing production volume demands.

3 OBJECTIVES

The criticality of Blast Freezing as a production step and the possibility of Blast Freezers becoming bottlenecks in the near future necessitated a dynamic capacity analysis. Also, if the capacity analysis found Blast Freezers to be possible bottlenecks, the management also wanted to know the specific scenarios under which Blast Freezers would become bottleneck and proposed remedies. The management also asked for proof as to how these proposed remedies would alleviate the bottleneck scenarios. Based on these analysis and results, the management was looking for a proposal as to how many extra Blast Freezers should be procured. To address these questions, we set the following objectives:

- Analyze the Blast Freezer capacity for different production load scenarios arising in years 2002 through 2006.
- Identify conflicts, suggest remedies and test the remedies using capacity analysis model.
- Recommend whether to procure more Blast Freezers and if so, how many should be procured and by when.

4 SCOPE AND ASSUMPTIONS

This analysis encompassed the Blast Freezing workload generated by regular production operations including historically observed uncertainties and variability. In order to focus on Blast Freezers as a resource, we assumed an adequate availability of manpower and utilities to run Blast

Freezing operations. We also took advantage of the high reliability of Blast Freezers (no significant production down time due to Blast Freezer in the recent past) and modeled normal operations, excluding extreme failures.

5 APPROACH

We decided to use simulation as a tool due to the non-linear and stochastic nature of the problem. The simple and robust simulation tool, SIGMA®(Schruben, 1994), allowed us to develop a reliable model and an adequate number of runs and replications to reach conclusions. We first mapped the process of Blast Freezer usage in terms of events, rules and timings. Our analysis approach after process mapping consisted of three stages.

1. Quick static capacity analysis to find out if there was acute and present need for extra Blast Freezers.
2. Detailed dynamic capacity analysis to estimate the impact of variability, uncertainty and operating rules.
3. Development and testing of operating policies to minimize the need for extra Blast Freezers.

6 STATIC CAPACITY ANALYSIS

We first calculated the workload in terms of hours of Blast Freezer time for peak production rates in all four areas. Then, we developed a simple capacity-loading graph (shown in Figure 1 below) for the worst case operating workload. The purpose was to have a quick estimate of the magnitude of need for extra Blast Freezer.

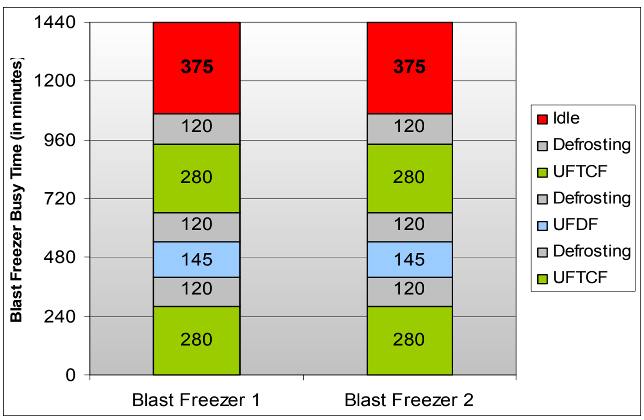

Figure 1: Static Capacity Analysis Graph

As can be seen in Figure 1, under zero variability, there is enough capacity to support the worst case workload with more than 6 hours of idle time on each Blast Freezer. This analysis indicated that there might not be any need for extra Blast Freezers.

7 DYNAMIC CAPACITY ANALYSIS

At the same time, we knew of certain operating rules that were in place to ensure that certain intermediate product carries higher priority for Blast Freezing. In fact, on the days when this intermediate was expected to be blast-frozen, one Blast Freezer would be blocked (kept idle) for the whole day to be ready for this priority workload.

On the other hand, the variability in the workload start times (i.e. the arrival time for intermediate product workloads) was significant enough to create interference that would cause waiting times for the workloads. We would like to elaborate this situation in detail. The static analysis from Figure 1 indicates 26% idle time per day with an important assumption of zero variability. As we know, the real life is far from zero variability. Common causes of variability in these operations have been upstream process time variability, shift changeover delays, product quality and operating parameters of upstream process (e.g. whether the upstream process is running at 100% capacity, 80% capacity or 50% capacity). These events create a domino effect on the schedule of a shared resource like Blast Freezer and in the long run, even small time delays add up to create inordinately long delays. The long delays are unacceptable mainly due to their impact on the product quality and also due to the chaos caused in operations due to delayed Blast Freezing. These issues led to a need for discrete event simulation model. The SIGMA model was built to mimic the Blast Freezer usage incorporating the existing operating rules and variability. Figure 2 shows the pictorial view of the model.

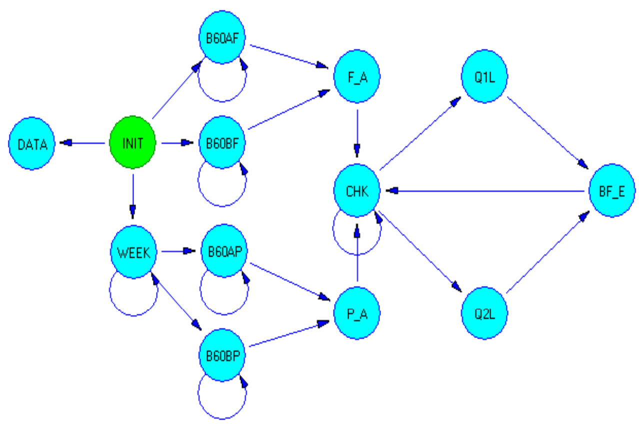

Figure 2: SIGMA Simulation Model

The simulation model was developed using standard techniques. The model begins with setting experiment parameters (INIT node). Then, the model sets weekly manufacturing calendar in terms of scheduled workload (WEEK node). Afterwards, there are four nodes that generate Blast Freezing workload mimicking the real life processes. These workloads are aggregated into two types at nodes F_A and P_A. This aggregated workload is then prioritized at the

CHK node. Based on the availability of the Blast Freezers, the workload is processed at nodes Q1L and Q2L nodes. The node BF_E frees up the blocked Blast Freezer resource when the workload has been processed (making it available for the next job in the queue). The DATA node was used to collect the outcomes of each experiment which included minimum and maximum waiting times, queue lengths, Blast Freezer utilization and total workload processed.

Validation of the model was done by comparing the simulation results with experience on the floor and operating parameters.

After validating the model, we decided to run six specific scenarios to understand the current and future operating environment. These scenarios depicted the future operating environments until year 2007. For each scenario, we ran four experiments, representing a 2x2 grid of two operating policies and two different numbers of Blast Freezers available. Each experiment had 40 replications with different random number seeds. The simulation was run on an Intel Pentium-III laptop with 256 MB RAM. Each experiment took less than a minute to complete.

The simulation results were obtained by analyzing the outcomes of 40 independent replications per experiment using standard basic statistical techniques (means and standard deviations, histograms and confidence intervals)

The simulation results indicated that the workloads would face waiting times (average of 2 hours and the worst case wait of up to 20 hours for the low priority workload, average of 40 minutes and the worst case wait of up to 6.5 hours for the high priority workload) under the worst case operating conditions.

Interestingly, the waiting times were not resulting from lack of capacity (None of the experiments showed Blast Freezer utilization in excess of 70%), but because of the operating policies that we had in place. The results brought us at a decision point as to whether to recommend purchase of two new Blast Freezers or to try a change in existing operating policies.

8 EFFECT OF OPERATING POLICIES

We decided to challenge the current operating policies. We took a second look at the most recent historical data on start times of one of the intermediates. We found that the predictability of start times has improved significantly over the recent past (six months). After discussions with engineering and manufacturing, the root cause for improved predictability was found to be certain operational improvements implemented. These improvements were not temporary and hence, we decided to take advantage of these changes.

We tried two different policies, one was FIFO (i.e. do not keep any Blast Freezer idle in anticipation of priority workload) and the other was where we reduced the blocking time by 50% (i.e. instead of keeping the Blast Freezer reserved for the whole day for priority workload, keep it blocked only for half a day).

The FIFO policy reduced average waiting times significantly, but penalized the intermediate product that required minimal waiting time (longer waiting times have adverse impact on key product properties). Hence, even if this policy was making sense from operations management perspective, it was not acceptable from process technology point of view.

The other policy of reducing the blockage by 50% produced more acceptable and encouraging results. Figure 3 below shows the impact on mean and maximum waiting time (in minutes) observed for this other policy.

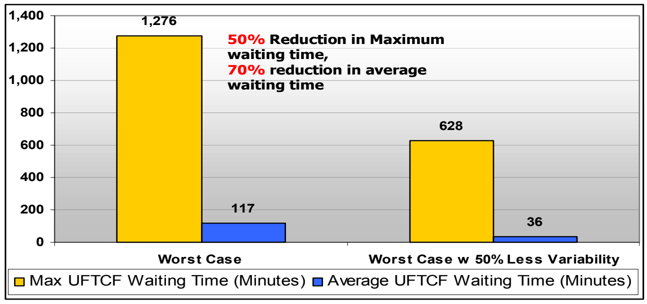

Figure 3: Effect of Changed Operating Policy

The experiment with the changed policy showed the potential of better utilization of existing Blast Freezer capacity. The experimental outcome also indicated that the solution to ensuring sufficient Blast Freezing capacity was not necessarily more Blast Freezers.

A secondary outcome of this changed policy was also suggested target start times for different workloads and time windows around these start times. These time windows and target start times would help scheduling of daily and weekly tasks in the affected manufacturing areas. Table 1 below illustrates the sample time windows and targets.

Table 1: Target Start Times and Windows

Workload	Target Start Time	Time Window
UFTCF-A	~ 02:30	00:00 to 05:15
UFTCF-B	~ 09:00	06:40 to 11:55
UFDF-A	~ 16:00	13:20 to 18:35
UFDF-B	~ 16:00	13:20 to 18:35

9 CONCLUSIONS

Discrete event simulation was successfully used for a quick and robust analysis of capacity requirements for a resource shared across multiple manufacturing areas.

Effectively utilizing the problem environment, namely, Operating policies and reduced variability in start times, enabled this project to be completed in less than eight weeks from start to finish.

Ensuring sufficient capacity does not directly translate into buying more resources. Trying out operational policies can provide significant gains in existing capacity utilization. The project recommended purchasing one extra Blast Freezer instead of two as planned. The extra Blast Freezer is intended more for reliability purposes and less for capacity purposes.

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