Throughput Analysis in a Frozen Food Processing Facility

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Abstract

Efficient use of resources in a production line that processes multiple product types with high volume of demand is necessary for overall success in many production facilities. Motivated by a problem in a frozen food processing facility, we analyze effects of several factors on the net throughput of heavily loaded production lines. The net throughput is affected by the amount of rework and experienced downtime. We identify factors and levels that would lead to improvement in these performance measures.

Keywords

Productivity, Throughput Analysis, Production Planning

1. Introduction

Frozen food processing industry is characterized by having multiple product types with high volumes produced in multiple lines. The production lines are automated or semi-automated, which run at very high production rates (speeds) as compared to traditional slower-pace assembly lines. These characteristics cause the activities performed in a frozen food processing facility to be interrelated like a spider web where the performance of a single activity or production line might affect the overall success of the production plant. Therefore, it is extremely important to coordinate and schedule the activities in an efficient manner. There are two important factors worth to mention that affect the overall performance in the frozen food industry: (1) USDA regulations, and (2) consumer compliance. For this reason, sanitation activities required by the USDA have a direct impact in the performance and they warrant special attention. Consumer compliance and overall customer satisfaction are important in any industry but in food industry the impact is even greater mainly due to direct and quick feedback from unsatisfied consumers. In any case, any product with a USDA or a consumer compliance problem has to be either discarded or reprocessed, hurting the performance of the production line.

Motivated by the complexity of the operations in a frozen food facility, we analyze the factors that affect the performance of the production lines. We propose and implement our initial solutions that lead to a continuous improvement in the measures of performance. We also develop a model that allows predicting the net throughput as a function of the downtime in the first hour of a shift so that actions can be implemented to improve the performance during the rest of the day.

We define the following terms used throughout the paper:

Up time %:	A measure of performance of how efficient the production line is operating. It is the percentage of time that the line is available (up) for processing. Uptime % is usually less than 100% due to rework, lines stoppages, and downtimes.
Actual line speed:	Production rate in units per minute at which the production line is set.
Net line speed:	The net throughput in units per minute that the production line performs, usually strictly less than the actual line speed.
Light weights:	Units that are rejected because of their net weight being below a specified tolerance.
Rework:	Products that have been rejected and have to be reprocessed before the shift finishes
upm:	Units per minute that the line speeds (actual or net) are defined.

In the first phase of the project, we initially study the factors that affect the performance of two selected production lines (called lines 1 and 2). The initial activities included the following: (1) Observe the line performances during operating hours. (2) Attend to production department daily meetings. (3) Analyze the production department reports. (4) Meet with the departments that have direct influence on the performance of the lines and obtain information on the key factors of performance. The departments included: Maintenance, Sanitation, Microbiology and Compliance. The feedback that was obtained from this initial attempt was that the following key operating factors affect the uptime %, which determines the final/net output of the line:

- Rework.
- Sanitation and maintenance performance during the third shift.
- (Actual) speed of the line.
- Downtime %, which is due to stoppages, breakdowns, machine fatigue, etc.

Once the key operating factors were defined, a deeper analysis of the daily production reports was conducted to find the root causes of the factors. The result of this analysis defined a correlation between the downtime % of the first hour and the overall daily performance (Uptime %). Since the performance of the first hour was linked to several factors and activities through several departments (including sanitation and maintenance whose activities in the third shifts leads into the first hour of the production shift), an overall strategy was implemented in order to improve the first hour performance. Due to the confidentiality of the information gathered from the facility under consideration, all the performance data has been normalized to 100.

2. Operations Analysis

2.1 Uptime and Downtime Analysis

Production reports for the past six months were analyzed with the purpose of identifying the factors that have an effect in production line 1. According to the information obtained from the maintenance department some mechanical changes were made in line 1 before, therefore we concentrated on analyzing only the September 2001 performance. The results obtained from the analysis are presented in Figure 1 and Table 1. As we can see in Figure 1, the 1st hour downtime % shows a correlation with the overall shift uptime %. That is, if you have a bad start you have a bad day performance. These results were presented to the departments that were consulted in the first stage of the study, and a general consensus was obtained that the first shift did not receive the line properly tuned from the third shift, during which sanitation and maintenance activities are performed. Due to the impact of the 1st hour performance with lost daily capacity of 2%, it was suggested that a study should be done to evaluate the operations during the third shift.

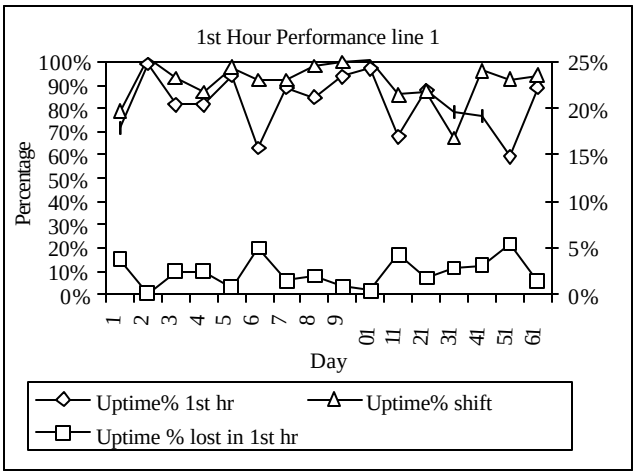

Figure 1. Daily Uptime % vs 1st Hour Performance

Table 1: Effects of the first hour

Totals per day	
Uptime% day	92 %
Report Downtime Minutes	58.64
Ocurrences	50.75
Total 1st hour	
Uptime %	82%
Report Downtime Minutes	11.0
Ocurrences	9
Total Uptime % lost	2%
% of total downtime	18%
% of total occurrences	17%

These results were presented to the departments that were consulted in the first stage of the study, and a general consensus was obtained that the first shift did not receive the line properly tuned from the third shift, where sanitation and maintenance are performed. Therefore, a study was done to evaluate the third shift activities.

2.2 Third shift activities

With the objective of evaluating the activities during the third shift a team was formed including people from the following departments and areas: Industrial Engineering, maintenance, compliance, microbiology, sanitation and the University of Arkansas. A study was performed during the whole shift and the following conclusions were made:

Production: Both lines had a lot of rework to process after the regular shift finished. Production supervisors did the rework at the end of the shift, which stole time from the sanitation and maintenance activities. It is important to notice that due to USDA regulations any sanitation activity cannot start in any of the two lines until both lines stop completely. The time taken to do the rework varies from 15 to 40 minutes every day causing a late start in sanitation and maintenance every day.

Sanitation: There are only two supervisors for the whole plant, supervising 87 people. They have to assign the job, control, supervise and check if the sanitation is done properly so that the lines can start operations the next shift. Their main problem is that the sanitation department has a big turnover and absenteeism rates, making very difficult for the supervisor to do the job scheduling every day. Due to the late finish (rework) of the production areas, the sanitation crew had several idle periods every day.

Maintenance: In general maintenance had a very good performance; even though they received the lines running out of time, they finished on time. They were doing as much as they could while sanitation was working on the line. However, as in the sanitation activities there are several idle periods during the shift in the maintenance activities.

In general, from this study we could conclude that receiving the line properly set in the first shift depends not only in any specific key-operating factor but also in the relationship among those factors. The effects of these factors can be understood in the diagram shown in Figure 2. As we can see in the diagram it is a vicious cycle where one factor affects all other factors in chain. To determine the root cause of this cycle, a deeper analysis in these factors is presented in the next section.

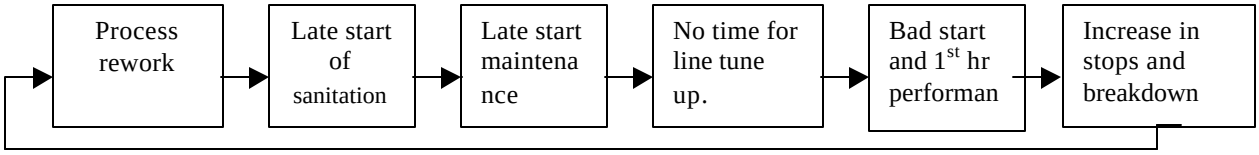

Figure 2: Effects of key operating factors

However from this study we can also conclude that more supervision is required in the third shift for sanitation and maintenance activities, a coordinator who reschedules the activities if necessary according to the time left. Also overlapping activities between sanitation and maintenance can be scheduled. The objective is to avoid dead times for sanitation and maintenance, for example, while sanitation is working in one end of the line, maintenance can work in the other end. Moreover, once sanitation finishes, the personnel can help maintenance in some operations that do not require skills in maintenance, like disconnecting or connecting parts of the equipment [1]. Cross-training some of the workers in both areas and using flexible work skills could improve the performance of the overall third shift activities.

2.3 Daily production reports

Once we knew that sanitation and maintenance were not the only factors to affect the daily production performance, the analysis next concentrated on evaluating the effects of the actual line speed on different product types and its effect on the net throughput. Intuitively, one thinks that increasing the actual line speed will increase the net throughput (i.e., faster input will result in higher output). However, the adverse effects of really high speeds could diminish the benefits and cause stoppages, machine failures, and quality problems due to equipment or workers. For these reasons, output data from the daily production reports were analyzed for a period of four months (July trough October) whose results are presented in Table 2. Figures 3 and 4 show the measures of performance versus product

types (called UPC, not actual product codes in the company, they are modified due to data confidentiality) for production lines 1 and 2.

Table 2. Average performances from July trough October for Lines 1 and 2.

Line		1st Hour Net Line Speed (upm)	Net Line Speed (upm)	Uptime % 1st Hour	Uptime % (daily)	Actual Line Speed (upm)
1	Mean	72.42	80.64	76.56	84.34	98.78
	Std Dev	7.73	7.26	8.31	7.37	0.73
2	Mean	72.29	82.93	78.09	88.79	97.22
	Std Dev	8.70	3.25	8.95	3.23	0.33

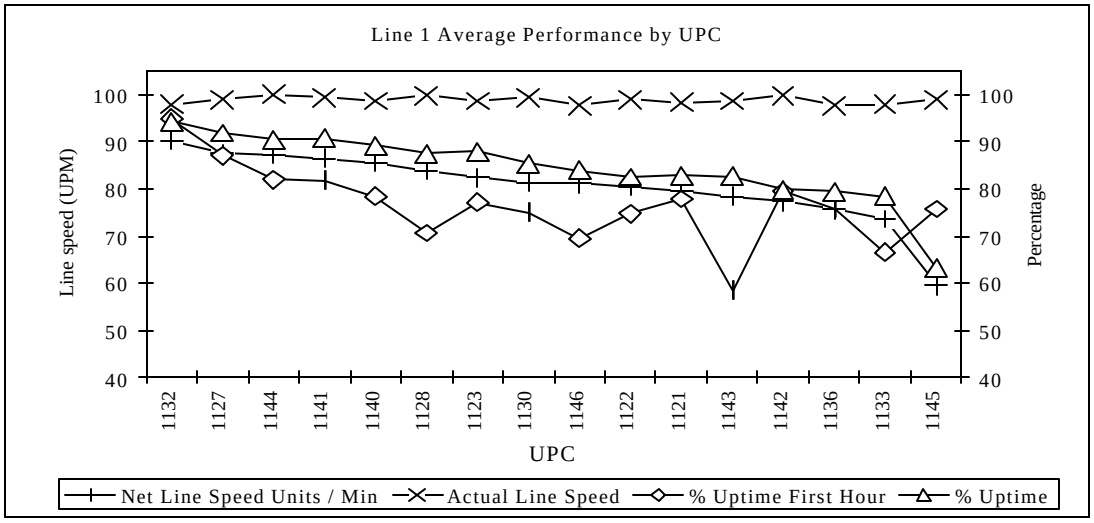

Figure 3. Line 1 average performance versus UPC.

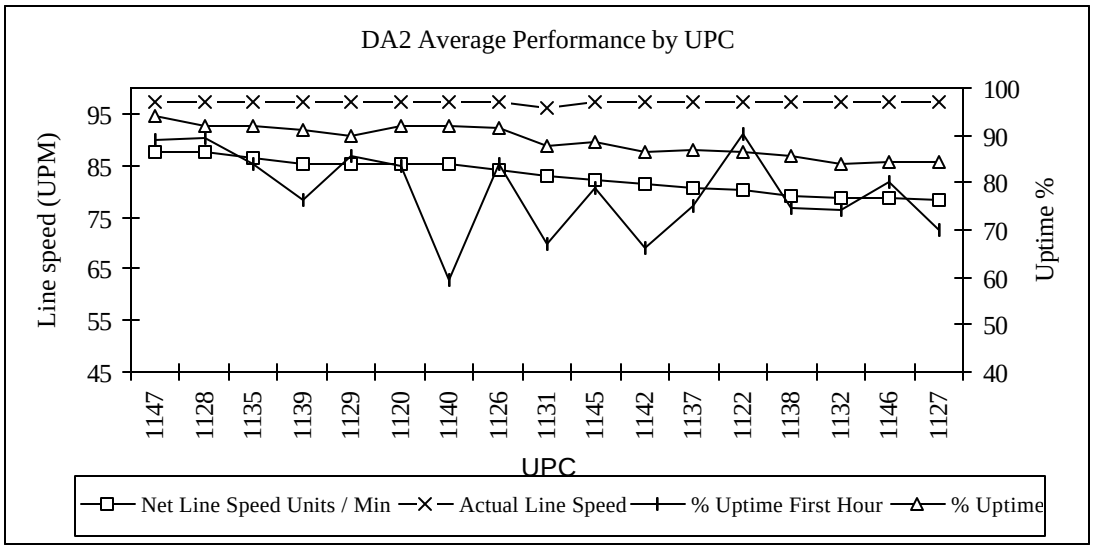

Figure 4. Line 2 average performance versus UPC

The following conclusions were obtained:

- Line 2 runs at a lower actual line speed (97 upm) but it has a higher net throughput (net speed).
  - Average net output for line 2 is 82.93 upm vs. 80.64 upm for line 1.
  - The performance of line 2 is more stable, i.e. less variable (Standard deviation of 9.62 vs. 21.50). Knowing that variability adversely affect the performance [2], we focused on strategies that would reduce overall variability.
- Actual line speed has a different effect on the performance for each product type.
- As observed before, the uptime % is strongly correlated to the performance of the line during the first hour.

2.3 Correlation between 1st hour performance and net throughput

The factor that has a significant impact in the net throughput is the downtime in the first hour, 2% of the shift capacity is lost in the first hour, which could otherwise be used for net products. Besides, the first hour usually reflects the performance of the day; a bad start (see Figure 2) usually means a bad day. Therefore, a simple regression analysis is done to evaluate the correlation between the downtime in the first hour and the shift net throughput as an initial analysis [3]. For the purpose of this paper, a product type for each line was selected (presented in Table 3). In general, though, a separate regression analysis could be performed for every product code.

Table 3. Regression analysis for lines 1 and 2

Line1 UPC 1136	Coefficients	Std Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	83.92	1.913	43.879	8.029E-11	79.512	88.333
Slope	-0.544	0.151	-3.611	6.870E-03	-0.892	-0.197
Line 2UPC 1139	Coefficients	Std Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	90.340	0.757	119.29	9.448E-24	88.726	91.954
Slope	-0.323	0.0355	-9.085	1.74E-07	-0.399	--0.247

The computed statistics and the coefficients of determination (0.62 and 0.85 for lines 1 and 2) show that there is some linear association between 1st hour downtime and the net throughput in both lines. As expected from the previous visual results (Figures 3 and 4), we have different intercept and slope (rate of change in the net throughput per unit of downtime in the first hour) for each product type. Hence, the regression models for the net throughput for lines 1 and 2 are:

Net throughput UPC 1136 line 1 = 83.92– 0.544 * Downtime 1st hour (1)
Net throughput UPC 1139 line 2 = 90.34– 0.323 * Downtime 1st hour (2)

3. Initial Implementation

Our initial recommendation and implementation has focused on two issues: 3rd shift activities and control of actual line speed. In frozen food industry, the sanitation and maintenance activities are tightly linked to the rest of the activities, especially production operations. For example, USDA requires that for every two production shifts, there must be one sanitation shift. Moreover, there is a half an hour sanitation period between two production shifts in a line. With respect to the sanitation and maintenance shift (3rd shift in our case), the whole production line is disassembled, cleaned with special chemical products and assembled back. This procedure is done every day through the whole year. In the case that the maintenance people do not set back the production line properly, due to any reason, the first shift will have a bad start and subsequently there will be a bad production day.

Therefore, the role of sanitation and maintenance is key to have a good start. In order to improve the performance of sanitation and maintenance the following recommendations were implemented:

- A maintenance-sanitation coordinator was assigned to the third shift to coordinate and schedule the activities.
- A time-based study for scheduling sanitation activities is being performed.
- Overlapping activities of sanitation and maintenance are being scheduled to avoid unnecessary idle times in both crews.
- Improve the supervision of sanitation by assigning a flexible schedule to the sanitation manager covering part of the third shift and part of the first shift.

Another important opportunity area for improvement is to standardize the performance of line 1 to the level of performance of line 1. One observation is that supervisors in line 2 reprocess the rework during the shift, during breaks and the lunch time, while line 1 reprocess all the rework at the end of the shift. Since line 2 is getting 2.29 units per minute more than line 1, the standard for production line 1 is being set to at least achieve the net throughput of line 2.

With respect to the effect of the line speed, the Production Operations and the Industrial Engineering Personnel undertake an analysis of the performance of the lines at different line speeds by UPC. Lowering the line speed seemed to have a significant resistance from the personnel (since it is counter-intuitive), but with the analysis presented, the management decided to do a limited pilot study where different speeds (usually lower than the current one) are tried. The objective is to determine the optimum line speed by UPC. Before a controlled set of speeds are tried, the line speed is set at a pre-determined level according to the experience of the Operations Manager, and it is increased and reduced gradually according to the observed results, which are being monitored by the Industrial Engineering Personnel.

4. Results

The results obtained by the company during the month of November by implementing our recommendations are presented in Table 4. As the results show, there is a significant improvement in the performance of the lines, by an average improvement of 4% and 2.97% in net throughput for lines 1 and 2 respectively. The effort seemed to bring the performances of the two lines closer, which was one of the goals. Another important improvement is in the reduction of the variability in line 1. The standard deviation of the net line speed per day for line 1 was reduced from 7.26 upm to 4.67 upm, which indicates that the performance of the line is more stable, with potential improvement in predictability of the line performance.

Table 4. Comparative results

		Before				**After**			
Line		**1st Hour Net Line Speed (upm)**	**Net Line Speed (upm)**	**Uptime % 1st Hour**	**Uptime % (daily)**	**1st Hour Net Line Speed (upm)**	**Net Line Speed (upm)**	**Uptime % 1st Hour**	**Uptime % (daily)**
1	**Average**	72.43	80.64	77%	84%	78.17	83.86	83%	87%
	Std Dev.	7.73	7.26	8%	7%	7.49	4.67	8%	5%
2	**Average**	72.29	82.93	78%	89%	73.70	85.39	82%	91%
	Std. Dev.	8.70	3.25	9%	3%	15.07	3.44	15%	4%

5. Conclusion

The complexity of operations in frozen food industry requires a continuous analysis of its measures of performance in order (1) to maintain its actual level of performance and (2) to work towards its continuous improvement. The challenge is to undercover the complex relationships and correlations among the influential factors and use this knowledge to come up policies and plans to improve the overall system performance. An area of opportunity where the research will continue is to employ flexible work force and cross-trained skills in the areas of maintenance and sanitation. We believe that if in the third shift overlapping activities can be scheduled to multi-function workers, the unnecessary idle times will be eliminated (or at least reduced) allowing a very valuable time to set the line properly for the first hour.

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