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CHOOSING AMONG SEVEN BASES

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ABSTRACT

In this paper, the selection of a BASE Case was every bit as important as the simulation itself. The production team had been familiar with simulations and had used their results on previous projects. The team was concerned with the design of additional capacity for a current production line along with their ability to gain approval for the proposed project. They knew that simulation could be the basis for their decisions. But first they had to ask the right questions. This production line, at a major food manufacturer, had been simulated and reviewed. Since the original simulation, it was noted that the Cartoner speed and overall efficiency had been stated at too high a level. New simulations were required to support the project. While 88% efficiency had been used in the prior simulation, the historical efficiency was only at 60%. But that level of productivity would be considered unacceptable as a BASE to request the purchase of additional equipment.

1 OVERVIEW

The main focus of this paper concerns the selection of assumptions that provide the BASE for comparisons between the current production line and a redesigned line with added capabilities. The team was unsure of their understanding of downtime conditions on the line. While overall downtime includes both Routine and Major Downtime, typically simulations are based only on routine events. In this case, the inclusion of Major Downtime could be valid due to the equipment redundancies in the options being considered.

This project reviewed seven BASE conditions before selecting three Bases for comparison.

This paper concentrates on the development and selection of the seven BASE CASES. The production line's layout, speeds, control logic, strategies, and downtime will be included as necessary to provide an understanding of the BASE CASE issues. To this end, many of the specifics of the production line and its simulation have either been simplified or left out of the presentation. The BASE CASE options provide their own form of complexity.

2 THE PRODUCTION LINE

The production line is shown in Figure 1. The line includes Filling, Overwrapping, Cartoning, and Casing. The project scope provided a model of current line conditions with a comparison to several capacity increasing options. Scenarios considered the addition of a third Overwrapper and/or a second Cartoner.

The Base model of current conditions included routine downtime occurrences along with standard changeovers. The assumptions shown in Table 1 were used in the original simulation.

Table 1: Speed and Downtime Assumptions Used in the Original Simulation

	Current Speed	Maximum Speed	Downtime Percentage
Filler	112	135	4.5%
Overwrap: 2@56 upm	112	-----	1.5%
Overwrap: 3@45 upm	-----	135	1.5%
Cartoner	152	180	9%
Caser	180	204	6%

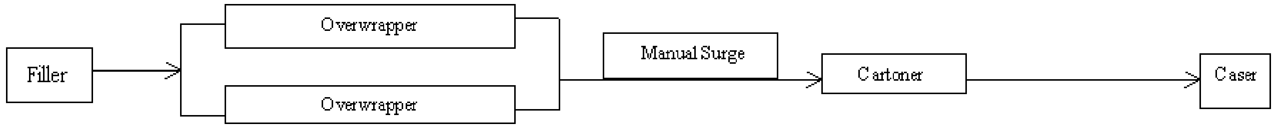

Figure 1: Flow Chart of the BASE Production Line

There is a 200 unit surge between the Overwrapper Merge and the Cartoner. The surge is accumulated and released manually.

The current line produces 112 units per minute. The surge allows the Filler and Overwrappers to continue operating when either the Caser or Cartoner go down for repair. When the Cartoner or Caser is repaired, units from the surge can be refed into the Cartoner while the Overwrappers are running. The maximum rate out of the surge is 40 units per minute based on manual handling. Therefore, the maximum rate to the Cartoner is 112 plus 40 = 152 units per minute.

Downtime percentages were provided by the plant based on a series of time studies. The downtime included routine stoppages in the range of 1 to 10 minutes per repair. Major stoppages beyond this range were excluded from the data.

The model of the current line was compared to models adding capacity to the line. One model added a third Overwrapper. The line speed would be increased to 135 units per minute, limited by the Filler. The Cartoner would be able to handle the combined maximum infeed rate of 175 from the Overwrappers (135) and from the Surge (40).

2.1 Production Line Strategy and Concerns

The successful operation of this line would limit the times that the Filler is blocked by downstream repairs. Filler blocks not only reduce productivity, but also affect the quality of the product. The best quality is derived from long uninterrupted Filling. A second concern is the avoidance of product remaining in the Cartoner Surge for over 20 minutes. Residence in the surge causes FIFO problems along with product quality issues.

The current layout blocks the Overwrappers and Filler when the Cartoner Surge is filled. The Filler and Overwrappers are restarted as soon as the Cartoner is able to run. The product is difficult to surge automatically. Also, the plant does not want to increase the amount of surge beyond the current 200 unit size.

2.2 Results of the Original Simulation

The original simulation showed that the current line produces 5880 units per hour with an overall line efficiency of 88%. The Carton Surge is filled 13 times per production day with a maximum residence time of 19 minutes. The Filler was blocked 18 times during the day.

Adding a third Overwrapper would allow the Filler speed to be increased to 135 units per minute. Production per hour would increase 19% to 6990 units per hour. At the higher rate, the Carton Surge would be filled 36 times during the day with a maximum residence of 22 minutes. The Filler would be blocked 42 times a day.

Since quality issues were increased by the addition of a third Overwrapper, a followup model added a second Cartoner along with the third Overwrapper. In this model, production increased 28% to 7570 units per hour. The Cartoner surge is only filled 10 times with a maximum residence time of 12 minutes. The Filler is blocked 9 times during the day. The addition of a second Cartoner to the simulation model improved quality and productivity compared to either current conditions or the three Overwrap model.

After reviewing the results, the Manufacturer was interested in adding the third Overwrapper in order to gain the higher line speed of 135 UPM. While realizing that quality issues had been raised by the simulation, the Manufacturer believed the results were reasonable enough to implement and improve through experience. Adding both an Overwrapper and a Cartoner would be unaffordable.

3 REQUEST FOR A REVISED SIMULATION

A few months after the original simulation, the Manufacturer decided to request a revised simulation. A test had been performed on the line providing units to the Cartoner at a rate close to 180 units per minute. It was found that the Cartoner was unable to produce at 180. Additional tests showed that even speeds of 145 units per minute caused frequent downtimes at the Cartoner. After testing, the Cartoner speed was reduced to 130 units per minute.

There was a second reason for requesting the revised simulation. The assumptions for the original simulation included routine downtime based on time studies. The model's 88% efficiency along with a percentage of Major Downtime would reduce efficiency levels to about 80%. Even though the Plant had never run at that level of productivity, they did not want to simulate their future conditions based on their current inefficiencies. Then, a few months after the original simulation, the Plant was suggesting that the simulation needed to better reflect current conditions as a BASE for adding new equipment. The 80% Target was deemed to be too high for a facility that had been producing at only 60%. They were more comfortable with a 70% Target for the current line and an 80% Target representing conditions after the production line had been upgraded.

3.1 Developing Assumptions for a Revised Simulation

While the Manufacturer wanted to change the assumptions for a revised simulation, it was not clear what assumptions to use. The realization that the Cartoner performed better at 130 units per minute had been determined only recently. The Plant had only a few days of experience at the reduced Cartoner speeds. The Standards were set at 70% even though the Plant was operating at 60%. The Manufacturer was unsure how to measure the benefits of the upgraded production line. What conditions should be used for comparison? Certainly improvements compared to the current 60% level would not be well received by management. The Plant knew it had to improve efficiency to support the addition of new equipment.

The downtime in the original model included only routine repairs of less than 10 minutes. When major downtimes occur in the current line, the entire line can be stopped until the repair is completed. A Cartoner failure stops the line in its entirety. A lengthy Overwrapper failure would allow the Filler to produce only at half speed. The Manufacturer suggested the possibility of including Major Downtime in the BASE because the new layout would allow production, even during major failures. The addition of a second Cartoner would permit production on one Cartoner even if the other Cartoner was down. Also, if one of three Overwrappers were down, the other two could maintain speeds of 112 units per minute.

There was a meeting convened to discuss what BASE should be used for the simulation. The Team included Plant, Engineering, Maintenance, and Division representatives. There were concerns about which BASE levels to use for efficiency, Cartoner speed, routine vs. major downtime, and downtime by machine. It was soon clear that a decision could not be made without a simulation of each BASE condition. It was decided to represent seven BASE conditions for further discussion. Those seven BASES are listed here:

1. Efficiency @ 68% Current routine downtime; no major downtime; Cartoner @ 145 infeed speed
2. Efficiency @ 60% Current routine downtime; major Cartoner downtime; Cartoner @ 145 infeed speed
3. Efficiency @ 60% Current routine downtime; major Overwrap downtime; Cartoner @ 145 infeed speed
4. Efficiency @ 73% Improved routine downtime; no major downtime; Cartoner @ 130 infeed speed
5. Efficiency @ 76% Future routine downtime; no major downtime; Cartoner @ 130 infeed speed
6. Efficiency @ 70% Future routine downtime; major Cartoner downtime; Cartoner @ 130 infeed speed
7. Efficiency @ 70% Future routine downtime; major Overwrap downtime; Cartoner @ 130 infeed speed

The speed and downtime assumptions were also changed for the revised model, as shown in Table 2.

Table 2: Speed and Downtime Assumptions Used in the Revised Simulation

	Current Speed	Maximum Speed	Downtime Percentage
Filler	112	135	8.0%
Overwrap: 2@56 upm	112	-----	1.5%
Overwrap: 3@45 upm	-----	135	1.5%
Cartoner	130/145	130/145	19%
Caser	180	204	9%

3.2 Simulations of the Seven Base Cases

Table 3 lists the assumptions, productivity, and specific statistics associated with each of the seven BASE CASES. The following sections provide a discussion of each BASE CASE and describes how each BASE was simulated

3.2.1 General Discussion of the Seven Base Cases

The simulations of the seven BASE CASES show pronounced differences compared to the Original simulation discussed in 2.2. Downtime is increased, major downtime is added in four of the BASE CASES, and the Cartoner speed is reduced to either 145 or 130 units per minute. Due to these changes, each of the BASE CASES has a lower efficiency, residency times in the Cartoner Surge that are beyond the acceptable limits, and more frequent stops of the Filler. While each BASE represents a set of different current or proposed assumptions, no BASE meets the plant's criteria for productivity and quality. The selected BASE CASES would be the starting points for improvement gained by adding equipment to the line layout.

3.2.2 Base #1: Efficiency @68%; Current DT; No Major DT; Cartoner @145 Units Per Minute

Routine downtimes were revised for these BASE simulations. While the Filler, Overwrapper, and Caser routine downtimes were understood, the routine Filler downtime provided a range of suggested values. It was agreed that the Filler downtime was higher than the 9% used in the original simulation. The model was used to determine the amount of routine Cartoner downtime that would cause the overall line efficiency to reach 68% without including major downtime. The Cartoner surge absorbs some of the Cartoner downtime. The simulation tested several levels of downtime based on the Cartoner speed of 145. The combination of 1 to 2 minute downtimes plus 8 to 10 minute downtimes totaled 25.6 % creating a line efficiency of 68 %. If the individual downtimes are added, they total 44.2 %. Therefore the cartoner buffer reduces the line's overall downtime to 32 %.

Table 3: Simulation of Seven BASE Cases; Data Represents One Day's Production

	BASE #1	BASE #2	BASE #3	BASE #4	BASE #5	BASE #6	BASE #7
Basis for Routine DT	Current	Current	Current	Improved Current	Future	Future	Future
Major DT	None	Cartoner	Overwrap	None	None	Cartoner	Overwrap
Major DT Minutes	-----	2 @ 70 min	2 @120 min	-----	-----	2@48 min	2@70 min
Cartoner Infeed Speed	145	145	145	130	130	130	130
Equipment Downtime:							
Filler	8.2%	8.8%	8.7%	8.2%	8.8%	8.5%	8.5%
Overwrappers	1.5%	1.5%	10.6%	1.7%	1.7%	1.7%	7.4%
Cartoner	25.6%	34.3%	25.9%	18.9%	15.6%	22.3%	15.2%
Caser	9.1%	8.4%	9.1%	8.9%	6.4%	6.2%	6.4%
	44.4%	52.0%	53.3%	36.7%	31.5%	37.7%	36.5%
Cartoner Surge:							
Times Filled	70	64	57	74	51	46	37
Max Residence Time	32 min	90 min	25 min	31 min	32 min	60 min	29 min
Avg Residence Time	8 min	10 min	6 min	11 min	10 min	12 min	8 min
Filler Blocks	102	86	103	100	83	72	85
Units/Hour	4560	4008	4044	4878	5115	4695	4687
Efficiency	68%	60%	60%	73%	76%	70%	70%

3.2.3 Base #2: Efficiency @60%; Current DT; Major Cartoner DT; Cartoner @145 Units Per Minute

BASE #1 above did not include any downtime over 10 minutes. BASE #2 is identical to BASE #1 except for the inclusion of two lengthy cartoner downtimes. Each major downtime has a duration of 70 minutes. In combination with all the other equipment downtimes, the line efficiency drops to 60%. This BASE represents the current actual conditions on Line #3.

3.2.4 Base #3: Efficiency @60%; Current DT; Major Overwrap DT; Cartoner @145 Units Per Minute

As in BASE #2, above, BASE #3 adds major downtime to the conditions modeled in BASE #1. BASE #3 adds downtime at one Overwrapper. In this example, two 120 minute downtimes were modeled to cause the line efficiency to drop to 60%. This model is based on one Overwrapper stopping while the remaining Overwrapper continues to operate at 56 units per minute. Filling is reduced to half - speed. When the Overwrapper has been repaired, the Filler is allowed to return to full speed.

3.2.5 Base #4: Efficiency @73%; Improved DT; No Major DT; Cartoner @130 Units Per Minute

Tests have shown that the Cartoner downtime is reduced when the speed is set at 130 units per minute. The simulation was used to establish the downtime percentage at the Cartoner that would create 73 % line efficiency. At 18.9 % Cartoner downtime, the line efficiency became 73 %. Because the Cartoner speed was lower than the 145 UPM speed in BASE #1, the average time that product stays in the cartoner surge is increased from 8 minutes to 11 minutes.

3.2.6 Base #5: Efficiency @76%; Future DT; No Major DT; Cartoner @130 Units Per Minute

A list of expected levels of future downtimes were inserted into the model. BASE #5 includes the downtimes associated with BASE #4 except that the Caser downtime is reduced to 6% from 9%. The simulated results indicated that a reduction in the Caser downtime would not change the overall line efficiency; it would remain at 73 %. Since the Caser operates at speeds up to 180 units per minute, it can offset some of its downtime as it receives units from the Cartoner at a maximum speed of 130. In order to reach the target efficiency of 76%, the projected Cartoner downtime @130 UPM had to be reduced from the current level of 18.9%. Simulation tests indicated the need to reduce the cartoner downtime in the future to 15.6 % from 18.9 % @130 UPM to reach the required levels of efficiency.

3.2.7 Base #6: Efficiency @70%; Future DT; Major Cartoner DT; Cartoner @130 Units Per Minute

Add major Cartoner downtime to BASE #5 to reduce the line efficiency to 70%. This was simulated by adding two 48 minutes Cartoner downtimes during the two shifts. The 70% efficiency represents future expectations of line improvement without the addition of either a Cartoner or Overwrapper. The entire line is stopped during a major Cartoner downtime.

3.2.8 Base #7: Efficiency @70%; Future DT; Major Overwrap DT; Cartoner @130 Units Per Minute

As in BASE #6, major downtime is added to BASE #5 to lower the efficiency to 70%. For BASE #7, the major downtime is represented by one Overwrapper stopping for 70 minutes during each shift. The addition of a third Overwrapper would reduce the effects of a major Overwrapper downtime.

4 SELECTING AMONG THE SEVEN BASES

BASES #1, #2, and #3 were eliminated even though they represented actual current efficiencies. The line standard was 70%. BASES #2 and #3 were only at 60%. BASE #1 was at 68% without including the Major Downtime that was part of the line's history. A further reason for eliminating these BASES was the high routine downtime level at the Cartoner. The 145 UPM speed caused downtime at 25%. Management would hesitate buying additional Cartoners for a line that already experienced higher than usual Cartoner Downtime.

BASE #4 was created to demonstrate how the line should operate when the Cartoner is reduced to 130 UPM. Since this change had been made only recently, the plant had not had time to build experience at this rate. The efficiency of 73%, along with Major Downtime would reduce the overall efficiency below the level of the line standard @ 70%. BASE #4 was eliminated.

BASES #5, #6, and #7 represented future downtime percentages that had not yet been achieved by the plant. However, the Team believed that the plant would have to demonstrate its ability to produce at these levels if Management were to agree to the proposed equipment additions.

Which BASE should be used for comparison. BASE #5 does not include Major Downtime. It represents how the line would run under typical circumstances. BASES #6 and #7 show the benefits of having redundant equipment. The addition of a second Cartoner and third Overwrapper would allow the line to be productive even during periods of Major Downtime. While it was hoped to minimize these conditions, Major Downtime occurs all too frequently. It was decided to use all three BASES #5, #6, and #7 for the comparison.

5 RESULTS OF THE REVISED SIMULATIONS: ADDING A SECOND CARTONER

5.1 Base #5: Efficiency @76%; Future DT; No Major DT; Cartoner @130 Units Per Minute

Without including major downtime, the addition of a second Cartoner improves efficiency from 76% to 89%. This efficiency improvement is based on the ability to run the second Cartoner at 130 when the first Cartoner is in repair, the ability to empty the surge at 40 units/minute even when the Overwrappers are producing at 112 units/minute, and the assumed reduction in Cartoner downtime from 15.6% to 10%. The use of the second Cartoner also helps to reduce the amount of Cartoner surge. The surge fills only 3 times during the day compared to 51 times with one Cartoner. The time in the surge is also reduced. Filler blocks have been reduced from 83 to 48.

5.2 Base #6: Efficiency @70%; Future DT; Major Cartoner DT; Cartoner @130 Units Per Minute

BASE #6 includes both routine downtime and two major Cartoner downtimes. The BASE #6 efficiency was 70%. The addition of a second Cartoner provides benefits during routine downtime and during the major Cartoner downtime. The resulting efficiency is 87%. Comparisons from the "Two Cartoner" simulation to BASE #6 shows improvement in the use of the Carton surge.The surge is filled only 23 times with two Cartoners compared to 46 times with one Cartoner. However, comparing the "Two Cartoner" simulation with major Cartoner downtime to the BASE #5 "Two Cartoner" simulation shows different results. While the second Cartoner has dramatically improved line efficiency, the one Cartoner working during the major downtimes causes the Carton surge to fill 23 times compared to 3 times without the major downtime. The one Cartoner working by itself, as in current conditions, has difficulty clearing the surge while handling the pies from the Overwrappers.

5.3 Base #7: Efficiency @70%; Future DT; Major Overwrap DT; Cartoner @130 Units Per Minute

Adding a second Cartoner provided major efficiency improvements to BASE #5 and BASE #6. In this case, BASE

#7 includes major downtime on one Overwrapper. While there is an improvement in the overall efficiency from 70% to 79%, the effects are not as strong as in the other two simulated cases. The downtime at the Overwrapper is not helped by adding a second cartoner. While this BASE #7 receives a benefit during routine downtime, the second Cartoner does not provide a benefit when the Overwrapper is down. The addition of a third Overwrapper, along with an increase in Filler speed, would provide significant efficiency improvement as shown in Section 6.

6 RESULTS OF THE REVISED SIMULATION: ADDING A SECOND CARTONER AND AN OVERWRAPPER

6.1 Base #5: Efficiency @76%; Future DT; No Major DT; Cartoner @130 Units Per Minute

Adding the third Overwrapper and increasing the Filler speed improves productivity to 7180 units/hour. This is a 40% improvement over the 5115 units/hour simulated in BASE #5. Even compared to the "Two Cartoner" simulation, there is a 20% improvement over the 6000 units/hour without the third Overwrapper. Increasing the line speed to 130 UPM causes the carton surge to be used more frequently than at the lower speeds of 112 UPM.

6.2 Base #6: Efficiency @70%; Future DT; Major Cartoner DT; Cartoner @130 Units Per Minute

When major Cartoner downtime is added into the simulation, there is very little change from the case with only routine downtime. The Units/Hour rate drops from 7180 to 6900. The surge is filled 31 times causing more frequent Filler stoppages. However, productivity has only decreased 4% from the routine downtime case. Compared to BASE #6, with one Cartoner and major cartoner downtime, the productivity improves 47%; 4695 units/hour to 6900 units/hour.

6.3 Base #7: Efficiency @70%; Future DT; Major Overwrap DT; Cartoner @130 Units Per Minute

The addition of the third Overwrapper helps the line efficiency when major Overwrapper downtime is included. When BASE #7 is simulated with two Cartoners and three Overwrappers, the units/hour rate increases from 4687 to 6665: a 42 % increase.

6.4 Discussion of Revised Results

Adding a second Cartoner improves productivity in the range of 14% to 17% compared to the BASE CASES. (#5, #6, and #7)

Adding a third Overwrapper to a line already including a second Cartoner further improves productivity in the range of 18% to 25%.

Adding a third Overwrapper and a second Cartoner improves productivity in the range of 40% to 46% compared to the BASE CASES.

It was decided to add the Cartoner as part of Phase I and the Overwrapper in Phase II.

7 CONCLUSION

The Manufacturer had been pleased with the results of the original simulation until they attempted to put their knowledge into action. They were interested in improving their productivity through the addition of a third Overwrapper. However, the 88% line efficiency used in the simulation did not resemble the historical productivity of 60%. In addition, it was learned that one Cartoner would be unable to run at the higher rates required to support an increase in Filler speeds. A second Cartoner would be needed as well as a third Overwrapper. The Manufacturer needed to provide a roadmap from their current efficiency to their long range objectives. Simulation was utilized to provide that roadmap along with the benefits that could be derived from each of the line improvements.

Once the decision was made to provide a revised simulation, it was clear that the BASE assumptions were difficult to determine. The Team used simulation to define each of the BASE CASES. Their understanding of the BASES and the proposed layout changes helped them select a strategy for the approval of their proposed capital project. The simulation enabled them to understand the improvements that needed to be made to the line performance before the project could be justified. The team had originally planned to add a third Overwrapper to allow an increase in the Filler speed. After the original simulation, they were concerned that the project could not afford both an Overwrapper and a Cartoner. The revised simulation showed that a phased addition of a Cartoner followed by an Overwrapper could be supported and justified.

The Team used simulation as a support tool for their line design and for their capital project. They discussed the information they needed from the simulation in advance. They had gained a better understand of the benefits and pitfalls of simulation during this project even though they had previously used simulation to solve problems. The previous simulations had provided answers to problems that could be implemented without major capital. This project required the Team's involvement in the simulation. They realized that they must be an integral part of defining the simulation's assumptions and specifying the simulation's answers. The Team was served by simulation and the simulation was served by the Team.

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