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A SIMULATION APPROACH TO CAPACITY EXPANSION FOR THE PISTACHIO HULLING PROCESS

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ABSTRACT

As part of a capacity expansion effort, simulation was used to evaluate the throughput of the current facility and future design options for the manufacturer of pistachios. By using simulation, Paramount Farms was able to select the design alternative that increased capacity at minimal cost. This paper describes the model used and provides details on the analysis performed.

Keywords: Manufacturing Simulation Application, Capacity Planning, Pistachio Processing, Discrete Event-Network Simulation

1 INTRODUCTION

Paramount Farms is a high volume quality manufacturer of pistachio nuts. The company has identified the goal of expanding market share of pistachio sales. However, currently no measure of system performance is available. In order to evaluate system performance/capacity simulation was chosen as the method of analysis because it easily lends itself to incorporating the complexity of the relationships between system components (Maggioli and Dessouky, 1992a &b).

Specifically, the objective of this simulation study was to take a chronological, year by year, approach to outline the necessary steps to expand capacity from the current level of 66 million pounds of pistachios to 79.2 million pounds of pistachios for the harvest in 1994 (20% increase), and to 92.4 million pounds of pistachios for the 1996 harvest (40% increase).

Output from the simulation model can provide the necessary information to determine how and where expansion can be implemented. For example, machine utilization statistics can aid in determining where the bottlenecks in the system exist and also where machines are under utilized. Also, daily throughput for different system design options can assist in determining the merit of the design.

In this study, streamlining and improving the efficiencies of the existing process were emphasized over purchasing new equipment when appropriate. Although the simulation model described here was developed in a specific context, the model is applicable to any hulling processing facility.

2 SYSTEM DESCRIPTION

Only female pistachio trees produce nuts. Male trees are mixed throughout the groves to cross pollinate. Pistachio trees bloom in April, and this is when the first indication of how the coming years crop will be. Pistachio trees are alternate baring trees, meaning that in alternating years they produce 50 percent more or less than the previous years production. This is the reason why capacity expansion is phased in two-year increments. Hence, in the lean years, the preparation and testing of the system enhancements can be performed. It is crucial that machine breakdowns do not occur during harvesting because pistachios only have approximately a 21-day window of opportunity for harvesting. Hence, the actual processing of pistachios for a calendar year occurs for only a small duration of time. The harvesting usually occurs in early October.

As the pistachio nut is being processed it loses weight. The pistachio is measured in two different weights: green and dry. Green weight is the weight of the nut, shell, and hull as it is shaken off the tree (35-45% relative moisture). Dry weight is the weight of the pistachio at 5-7% relative moisture. This is the water content that must be attained for storage and sale. At any time during the processing of the pistachio, the relationship between the green weight and dry weight can be expressed by the following formula:

$$\text{green weight} = (\text{dry weight} * 55)/(\%\text{M.C.} + 17)$$
where M.C. = moisture content in percentage

Approximately a 3:1 harvest to sale weight ratio is lost in the hulling/drying process. For example, a truck with 50,000 lbs of fruit will yield around 16,500 pounds of hulled pistachios.

Paramount Farms currently has 3 facilities which hull pistachio: New Huller, Old Huller, and Blackwell Huller. The Blackwell Huller is an offsite facility, and it is never used in off years.

The flow of operations for the production of pistachios is as follows: 1) Harvesting 2) Truck Scaling 2) Receiving/Precleaning 3) Hulling 4) Drying 5) Storing 6) Processing [scavenging, pinpicking, color sorting, hand sorting, natural packaging] 7) Roasting 8) Dying 9) Packaging [boxing, cello packaging, bulk shipping].

The hulling process is composed of steps 1 through 5. Since these steps are the ones which have a direct impact on the amount of pistachios which can be processed during a calendar year, they are the only ones simulated. The other steps are auxiliary operations which impact the quality of the pistachio and not the quantity produced. Thus, each of the facilities are modeled from when the truck arrives from the field and is weighed to when the pistachios are sent to the silos for storage. Steps 1 through 5 are discussed in more detail below. Figures 1 and 2 show the schematic of these operations for the New Huller and the Old Huller respectively.

Pistachios are harvested by shaking tree limbs and capturing falling pistachio in collection trays. The speed at which the harvest can take place is a function of the equipment used. Pistachio trucks coming from the field are then weighed as they enter the processing facility. The tare weight is known beforehand for many of the trailers. However, some trucks must be weighed to determine the tare weight either before or after they are received. Trucks hauling trailers will unhook the trailer on the scale to get the trailer weight only. There are 2 scales for the main receiving of pistachios. One scale can weigh a truck or trailer in 10 minutes. With two scales the daily capacity is 288 trailers per day.

Pistachio receiving and precleaning are viewed as one step. The receiving step can be described as simply opening the gate on the bottom of the truck. The pistachios flow from the truck through a receiving grate at ground level into a receiving pit. The cycle time for dumping a truck is entirely dependant upon the cleanliness of the product. If the pistachios contain many sticks and leaves, it is possible the truck will jam at the bottom, and the pistachios will have to be forced out using probing poles. If the pistachios are clean, the "dumping" of a truck into the receiving pit will take justa few minutes.

The precleaning operation is the conveying of the pistachios from the receiving pit and running them over an airleg to remove light sticks and leaves. The capacity of these conveyors differ for each of the three different hullers. This is due to physical size and conveyor speed.

Pistachio hulling is accomplished through abrasive action on the outside of the fruit to remove the outer skin or hull. This is accomplished in hulling tubs. A hulling tub will take a measured amount of pistachios, cycle them, remove hulls, and eject hulled pistachios. The New Huller and the Old Huller tubs operate in batch mode while the hulling tubs for Blackwell operate in continuous mode.

Drying is accomplished by either a flow through (continuous) convection oven process, or a batch convection process. The New and Old Hullers are equipped with flow-through dryers, and the Blackwell Huller has the batch type. The wet pistachio moisture content is approximately 40 percent before drying, and the normal dry storage weight is 5 percent. The drying processes will usually bring the weight from 40 to 10 percent. The balance of the drying occurs in the storage silos. The drying speed is very dependent upon relative humidity and ambient temperature.

Separate dryers are always reserved for drying the float pistachios. As the pistachios are ejected from the hulling bins they are placed in a water bath to separate non splits and small kernel pistachios from the normal pistachios. These floating pistachios are then dried so that the non splits can be artificially opened. The floating pistachios make up approximately 25 percent of hulled and dried material.

Silos will store the pistachios, and complete the drying process. If the pistachios are to be binned off, they first must be dried to 5 percent moisture content and fumigated in a storage silo. The dried and fumigated pistachios then flow from a storage silo over a scavenger which removes any large foreign material or unhulled pistachios. From the scavenger the pistachios are run through pinpickers to the next processing operations.

3 MODEL FORMULATION

The model of the hulling processes was built using the simulation language SLAM II (Pritsker, 1986). It provides network symbols (process view) for building graphical models that are easily translated into FORTRAN statements for direct computer processing. The simulation models that were developed for this study were entirely network models.

The 1992 harvest was used to collect the data for the simulation model since no reliable data existed prior to this period. At that time data concerning machine processing times, machine capacities, move times, and equipment (machines and conveyors) breakdowns were collected.

The simulation model is composed of three main sections: the precleaning\receiving operation, the hulling operation, and the drying operation. The SLAM model that represents the New Huller is explained in detail in this section. Only the significant differences between this model and the simulation models that represent the other

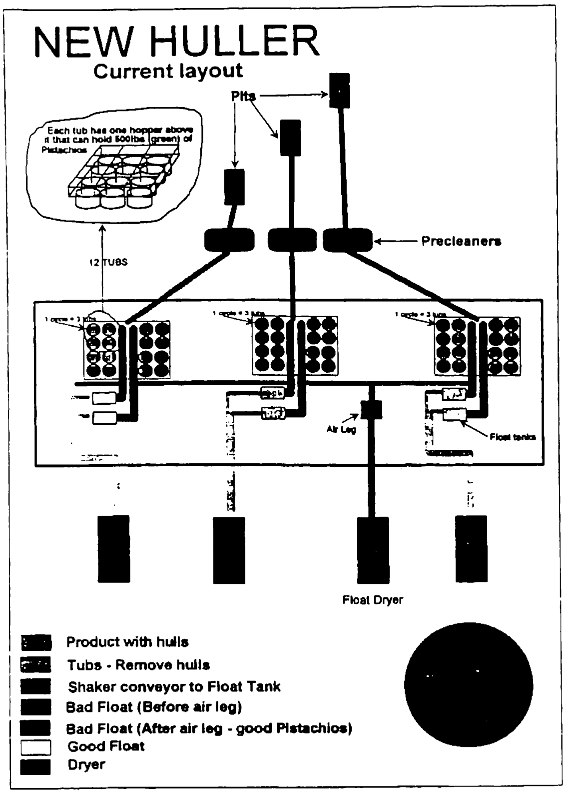

Figure 1. New Huller (Current)

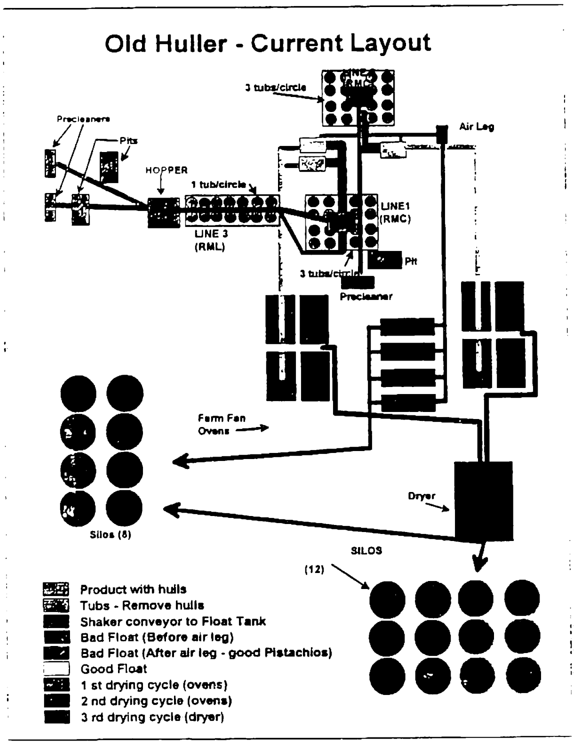

Figure 2. Old Huller (Current)

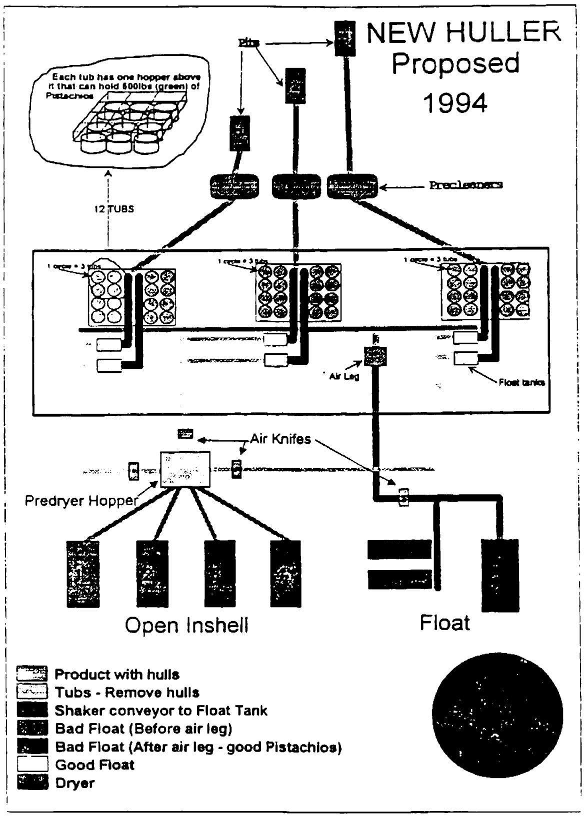

Figure 6. New Huller (Proposed)

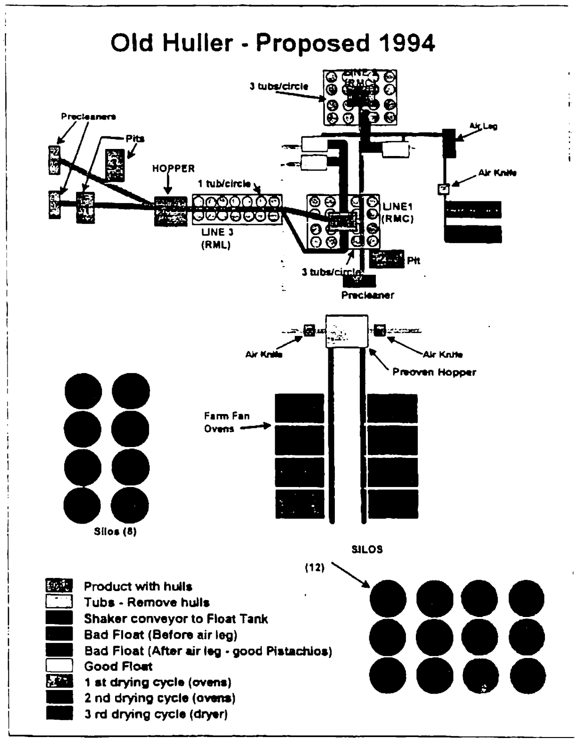

Figure 7. Old Huller (Proposed)

hullers will be discussed since analogy between those models and the New Huller model exists.

As shown in Figure 1, there are three identical lines that process pistachio in the New Huller. To avoid redundancy, the SLAM II model for the operation of line 1 is only presented since the logic associated with the other lines is identical with this line's logic. Because it is infeasible to model each unit of pistachio (not enough memory and long compilation time), the pistachios are batched into units of pounds represented by an entity. Green weight is always used in the model, and all time units are in minutes. Each truck contains an average of 47,250 pounds of pistachios. The attributes of the entities and the SLAM variables are listed in Table 1.

Table 1. Definitions of Variables in the ATRIB and XX Arrays

Variable	Definition
ATRIB(1)	Mark Time
ATRIB(2)	Processing Time at the Precleaner
ATRIB(3)	Weight (lbs)
XX(1)	The percent of pistachio that are float
XX(2)	The number of batches per truck
XX(3)	Flag blocking precleaner unloading
XX(9)	Counter for the # of finished batches
XX(12)	The total number of pounds produced

Figure 3 depicts the SLAM II network for the precleaning/receiving operation. The first logic associated with the precleaning operation is to determine whether the truck has finished unloading. If yes, the pits are then cleaned and another truck starts unloading. Note, the logic prevents the truck from unloading when the hoppers before the hulling tubs become full. This is accomplished by checking for hopper space before the hulling tub's logic is performed. The hopper spaces are represented by resources 25 and 26, respectively. If a space exists, the batch is sent to the hulling tubs, and another batch of pistachios are unloaded from the truck. If space does not exist, then the truck unloading process is halted, and the precleaner is set to idle. Free space in the hopper is checked again in 10 minutes.

Figure 4 depicts the SLAM II network for the hulling operation. The first step is to seize a free hopper space, and then to transfer the pistachios to the hulling tub. After processing at the tub, the float pistachios are separated from the open inshell pistachios (good pistachio). As stated before, the reason for their separation is that float pistachios are dried at a different dryer because they require a longer period to dry.

Figure 5 depicts the SLAM II network for the drying operation. The Dehydrator Dryers are used to dry the pistachios at the New Huller. Before the pistachios are transferred to the dryers, the pistachios are batched into 4 entities. Thus, creating a new entity with a weight of 480 pounds. The reason for this batch is that the pistachios have a very long drying time creating the adverse situation of having too many entities in the system if the pistachios (entity) remain at their current weight. SLAM II has a limit on the number of entities simultaneously in the system.

After batching the entity is transferred to the dryer. The dryers at the New Huller operate in continuous mode, and their capacity is to process approximately 33,000 pounds of pistachios per hour. An entity seizes a slot in the dryer for an average of 191 minutes. There are 217 slots per dryer. After drying, statistics are collected on the total pounds of pistachios produced and the average time in the system for the pistachios.

Even though the Old Huller facility is configured differently than the New Huller, the SLAM II logic that depicts the Old Huller is very similar to the New Huller's model. The only significant difference is the drying operation. As shown in Figure 2, pistachios processed by lines 1 & 3 are merged into one line after the hulling operation. The drying operation for the open inshell pistachios are performed by the Farm Fan Ovens and a Proctor Dryer. Currently, the Farm Fan Ovens utilize a two-stage operation. For instance if the pistachios arrived from lines 1 & 3, they are either sent to Farm Fan 1 or 2, then they are dried further in either Farm Fan 3 or 4. All open inshell pistachios are then sent to the Proctor Dryer in order for them to be dried to their required 10% moisture content.

The only significant different between the New Huller's simulation model and Blackwell's model is that the hulling tubs now operate in continuous mode. This is of minor consequence since these tubs can be modeled similar to the dryers at the New Huller but with a much smaller capacity and processing time.

4 VALIDATION

Validation of the model needs to be addressed before any sensitivity analysis can be performed. Validation is usually done by executing the model until a steady state is reached where output generated from the model can be compared to real data gathered from the process. By using records kept of the number of trucks that were weighed at the scale for the 1991 harvest, the average number of trucks/day was computed empirically.

In 1991 the average number of trucks processed for the 26 day operation was 64.9 trucks/day but this included start-up and shut down. When start-up and shut down are removed from the data 79.8 trucks/day were processed which is within 2% of the number (77.9

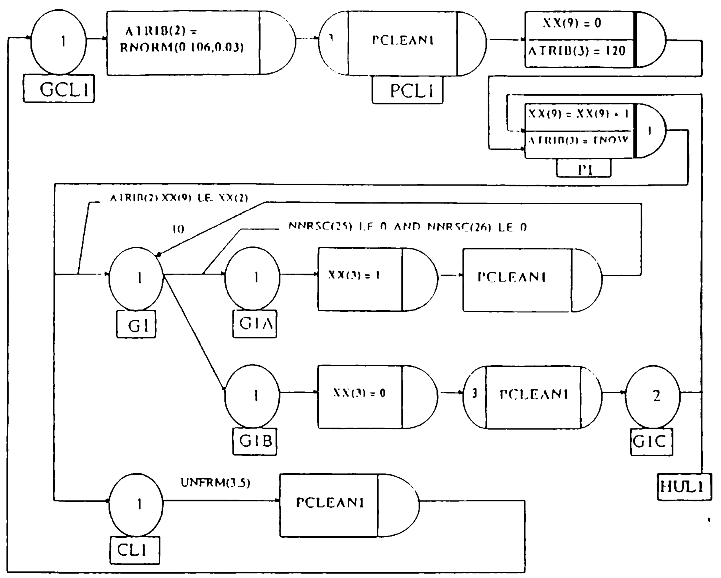

Figure 3. The Slam Network for the Precleaning Operation

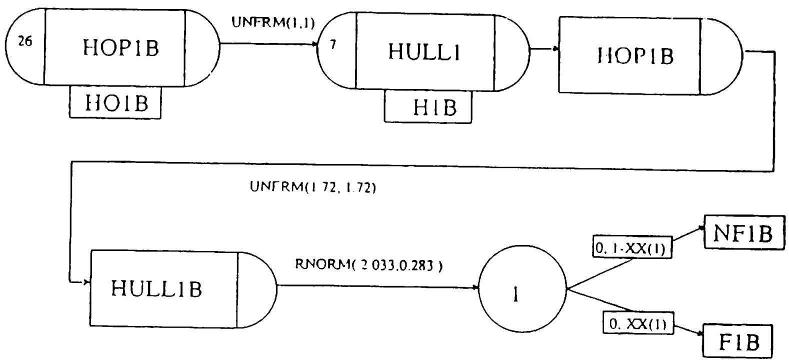

Figure 4. The Slam Network for the Hulling Operation

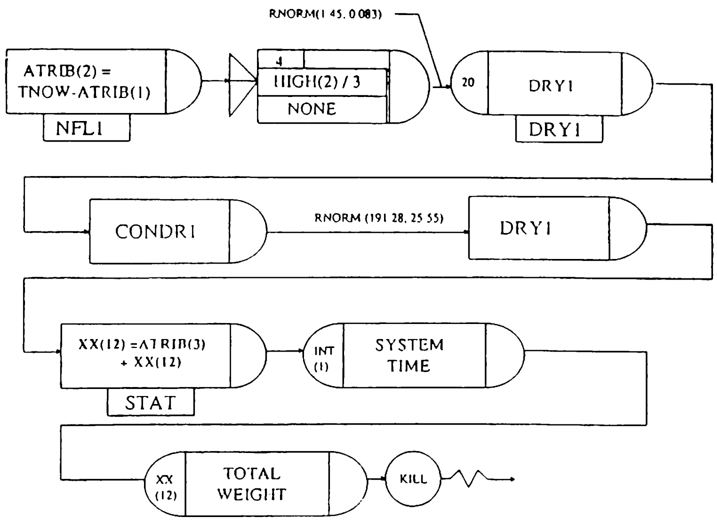

Figure 5. The Slam Network for the Drying Operation

trucks/day) generated by the simulation.

5 CAPACITY ENHANCEMENTS

Tables 2 and 3 show the simulation results for the current configurations and the recommended enhancements for the New and Old Hullers respectively. The definitions for the scenarios in Tables 2 and 3 are listed below and discussed later.

Table 2 Scenario Definitions
1992 - actual layout and data from the 1992 harvest.
1994A - data from the 1992 with layout in Figure 6.
1994B - same as above and improved precleaning time.

Table 3 Scenario Definitions
1992 - actual layout and data from the 1992 harvest.
1994A - data from the 1992 with layout in Figure 7.
1996A - data from the 1992 with layout in Figure 7 and improved precleaning time and an extra Bin oven.
1996B - Same as 1996A with two extra Farm Fan Ovens.

Recall, streamlining and improving the efficiencies of the existing process is emphasized over purchasing new equipment when appropriate. Note, no future enhancement was recommended for the Blackwell Huller. The reason being that at Blackwell the utilization of the machines are evenly balanced, and hence no major throughput increases can be achieved without a major sum of capital invested. The enhancements to meet the 1994 harvest requirements are first presented.

As shown in Table 2, the dryers are the bottleneck at the New Huller. Hence, it is recommended that the Proctor Dryer and two of the Bin Ovens be transferred from the Old Huller to the New Huller. In 1992 it was observed that the Proctor on average received pistachios with a moisture content of 12% (acceptable for silo drying). It was also observed several times that the Proctor's burners were turned off because product was too dry coming out of the Farm Fan Ovens and should not be dried further. The transfer of the two Bin Ovens can be justified by their low utilization (36%).

Figure 6 presents a schematic of the proposed new layout for the New Huller. The Proctor and two Bin Ovens are moved from the Old Huller to dry float at the New Huller. The Dehydrator Dryer that was used for float will now dry open inshell product with the other three Dehydrator Dryers. The open inshell product are routed to a common hopper to be evenly distributed to the four Dehydrator Dryers. With this new configuration, the precleaners now become the bottleneck. However, by conferring with expert opinion, it was decided that the truck unloading time can be improved by 10%. Table 2 shows the simulation results for this scenario 1994B.

With these enhancements made to the New Huller, an increase of 18.7 trucks per day can be achieved. Hence, a 6.8 million pound throughput increase (47500 greenlbs/truck x 18.7 trucks/day x 21 day x .365 drylbs/greenlbs) is obtained. The total processing capability of the New Huller for 1994 would be 40 million pounds.

The current process layout of the Old Huller can be improved with minimal major equipment purchases. The process lacks balance between resources such as the Farm Fan Ovens. It also handles the product too much between different drying processes (i.e. Farm Fan Set 1 to Farm Fan Set 2 to Proctor to silos). The goals for process improvement to the Old Huller are;

1) better balancing between resources - Farm Fans
2) minimize material handling - eliminate conveyors.

As shown in Table 3, the utilization of the first set of Farm Fan Ovens that dry product for lines 1 & 3 are 100% while the first set of Farms Fan Ovens that dry product for line 2 are 86%. A scenario was created and tested in which the Farm Fan Ovens and the Bin Ovens were rearranged to allow the ovens to accept and dry product from any line. Figure 7 presents a schematic of the proposed new layout for the Old Huller. Note, the 2 Bin dryers and the Proctor dryer have been transferred to the New Huller.

Benefits of this configuration are that it minimizes downtime by eliminating a three stage drying process for a single multi-oven phase and by eliminating extra material handling thus reducing conveyor problems which is the main source of downtime. For example, if one Farm Fan Oven breakdowns (or shut down for cleaning) it would only reduce drying capacity by 12.5% instead of 25%.

The proposed changes to the Old Huller would result in a 5 million pound throughput or 13.8 trucks per day increase for the 21 days. The total processing capacity of the Old Huller would be 25.5 million pounds projected for the 1994 harvest.

With the proposed changes in 1994 to the New and Old Hullers and maintaining the same production capacity for the Blackwell as in 1992, Paramount Farms can expect to process:

New Huller...................... 40 million lbs
Old Huller........................ 25.5 million lbs
Blackwell......................... 12.2 million lbs
1994 Total Capacity ----- 77.7 million lbs

As the simulation results indicated, Paramount Farms can achieve its 1994 capacity requirements with a minimal of capital expenditure. The enhancements are based on

Table 2. New Huller Simulation Results											
		# Trucks/Day				Average Utilizations					
Layout	Time in System (hours)	Open Inshell	Float	Float Overflow	Total	Pit & Precleaner	Hullers	OI Dryers	Float Dryer	Proctor	Bin
1992	4.1	57.9	14.5	5.5	77.9	86.7%	78.2%	99.7%	100%	N/A	N/A
1994A	3.6	68.8	23.3	-	92	98.0%	93.0%	89.1%	N/A	98.2%	74.1%
1994B	3.7	72	24.6	-	96.6	94.2%	97.1%	93.0%	N/A	99.1%	100%

Table 3. Old Huller Simulation Results																	
		# Trucks				Utilizations											
	Time in System	Open Inshell	Float	Float Overflow	Total	Pit 1 & Precleaner	Pit2 & Precleaner	Pit 3 & Precleaner	Huller 1 RMC	Huller 2 RMC	Huller 3 R & I.	Farm Fan Set 1a	Farm Fan Set 1b	Farm Fan Set 2a	Farm Fan Set 2b	Proctor	Bin Average
1992	3.5	41.2	14.4	0.1	55.7	69.0%	100.0%	68.0%	39.0%	50.0%	60.0%	98.0%	69.0%	86.0%	60.0%	90.0%	36.5 %
1994	2.5	2.5	16	1	69.5	98.0%	100.0%	98.0%	59.0%	52.0%	88.0%	91.0%	91.0%	91.0%	91.0%	N/A	100.0%
1996A	3.6	3.6	16.5	3.9	78.3	80.0%	98.0%	80.0%	67.0%	59.0%	81.0%	100.0%	100.0%	100.0%	100.0%	N/A	82.4%
1996B	2.45	2.45	16.5	5.9	86.9	97.0%	99.0%	97.0%	80.0%	58.0%	95.0%	89.0%	89.0%	89.0%	89.0%	N/A	90.5%

Table 4. Paramount Farms four Year Pistachio Hulling Capacity Study				
Year	**Goal**		**Proposed Improvements**	
	Million Pounds	**% Increase**	**Million Pounds**	**% Increase**
1992	66	0	N/A	N/A
1994	79.2	20.0%	77.7	17.7%
1996	92.4	40.0%	84.1	27.4%

reconfiguring the Old and New Hullers.

To meet the 1996 capacity requirements, the Old Huller is the huller which holds the most potential for improvement. It can be seen from Table 3 of the proposed process for 1994 that the bottleneck is now the pits & precleaners (truck unload time). All three pits & precleaners are nearly 100% utilized thus restricting the rest of the system. Two new scenarios were considered: 1996A and 1996B.

Scenario 1996A simulates the Old Huller with improved pit & precleaner unloading times. It also adds one Bin Oven to handle the increase in float material. Scenario 1996B builds on 1996A. The simulation of scenario 1996A showed that the Farm Fan Ovens were now the bottlenecks while the improved pits & precleaners were only utilized 86%. Thus, scenario 1996B adds two additional Farm Fan Ovens to relieve the drying bottleneck.

Based on this production plan the proposed changes in the Old Huller will result in a 6.4 million pound increase over 1994's proposed process and a 11.4 million pound increase over the current (1992) process. The Old Huller would have a total capacity of 31.9 million pounds in 1996 if the proposed changes are implemented.

With the proposed changes in 1994 and 1996 to the New and Old Hullers and maintaining the same production level at the Blackwell Huller as in 1992, Paramount Farms can expect to process:

New Huller...................... 40 million lbs
Old Huller........................ 31.9 million lbs
Blackwell .... 12.2 million lbs
1996 Total Capacity ----- 84.1 million lbs

6 CONCLUSION

Computer simulation was used successfully to assist in the development of a proposal to expand capacity at Paramount Farms Pistachio Processing Operations. The extra capacity was required in order to meet future demand. The simulation made it possible to take an objective look at the utilizations of individual pieces of equipment to see where bottlenecks were forming. Based on these utilizations we were able to more effectively balance the pistachio hulling and drying process. These proposed changes take the existing processes and pushes them to near their maximum capacities. High utilizations for each piece of equipment in the simulations indicate that the system is near its maximum capacity as shown in Tables 2 & 3. Table 4 summarizes the results of this study.

Paramount Farms is currently moving towards the implementation of the suggested enhancements to their facilities. The next significant increase in throughput will involve major equipment purchases. The 84.1 million pounds is near the maximum capacity of the process without major investment in new equipment. Based on the capacity goals and the proposed changes, the capacity in 1996 will fall short of the goals and will require management to evaluate the next logical progression to increase capacity to match demand.

REFERENCES

Maggioli, G., and Y. M. Dessouky. 1992a. "Computer Simulation of the Pistachio Hulling Process for Paramount Farms", Technical Report, Phoenix, AZ.

Maggioli, G., and Y. M. Dessouky. 1992b. "Paramount Farms Four Year Pistachio Capacity Study", Technical Report, Phoenix, AZ.

Pritsker, A. A. B. 1986. Introduction to Simulation and SLAM II, 3rd Edition. Halsted Press, New York, 1986.

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