Feasibility of a Tomato Processing Firm in Southeastern Oklahoma

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Abstract

This study uses a simulation model to analyze the impact of stochastic temperature on the flow of raw tomatoes into a tomato processing firm. The resulting random yields impact on the potential of the processing firm to make a profit. The impact depends upon the product mix, size of the processing firm, and the acres of raw product.

Results indicate that a large firm processing 400 acres of tomatoes a week has the potential to make a profit. However, a smaller firm processing only 100 acres of tomatoes a week has no potential to make a profit.

Oklahoma Agricultural Experiment Project H-2046

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Feasibility of a Tomato Processing Firm in Southeastern Oklahoma

Raymond Joe Schatzer, Abdulhamid A. Elmagsabi, and Daniel S. Tilley[1]

Tomatoes for processing are a principal vegetable crop produced in the United States. Processing tomato production output rose from 5.1 million tons in 1970 to 10.4 million tons in 1990, and accounted for about 65 percent of total processing vegetables excluding potatoes. The total value of the crop increased from $171.9 million in 1970 to $702.4 million in 1990 making it the second most valuable vegetable crop following potatoes. Processed tomato pack which consists of six major canned tomato products (canned whole tomatoes, tomato sauce, tomato paste, tomato juice, tomato catsup, and chili tomato sauce) has shown an upward trend to meet the rising demand for tomato products. Per capita consumption of canned tomatoes, which constitute the bulk of the canning industry, has expanded from 62.1 pounds in 1970 to 70.0 pounds in 1990 (farm weight basis). Table 1 shows the trends in total output, total value, and per capita consumption for processing tomatoes and the five major processing vegetables (tomatoes, green peas, sweet corn, snap beans, and cucumber pickles) for the United States, 1970-1990.

The growth in the tomato processing industry is largely attributed to the high demand for processed tomato products. This high demand has been linked to the expansion of fast food restaurants, along with changes in American lifestyles (Hamm, 1987; Brandt and French, 1981).

California became the major producer of tomatoes in the United States when its share of the supply expanded from 25 percent in the early 1950's to 88 percent in 1986 as production location shifted from the East (New Jersey, Pennsylvania, New York, and Delaware Peninsula) and the Midwest (Illinois, Indiana, and Ohio) due to the more favorable growing conditions in California. The rising demand for tomato products has propelled the growth of the tomato industry. Producers in other states are examining the industry as they seek more profitable crops and a more diversified agriculture.

In a study of 24 counties in southeastern Oklahoma, Williams and Badger (1982) indicated that some producers in the region were considering alternative crop enterprises, especially fruits and vegetables, since

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Table 1. Production, Value, and Per Capita Consumption for Processing Tomatoes and the Four Major Processing Vegetables for the U.S., 1970-1990.

	Processing Tomatoes			Major Processing Vegetables[a]		
Year	Production	Value	Per Capita Consumption	Production	Value	Per Capita Consumption
	Tons	$1,000	Lbs.	Tons	$1,000	Lbs.
1970	5,058,950	171,857	62.1	8,595,650	380,173	98.9
1971	5,515,550	195,738	68.3	9,257,150	409,920	105.5
1972	5,803,700	204,366	64.9	9,623,800	432,286	102.2
1973	5,934,550	249,085	58.4	9,973,100	510,467	96.4
1974	7,019,850	453,022	61.3	11,007,800	873,102	97.5
1975	8,503,750	537,452	61.9	12,807,050	979,109	96.5
1976	6,471,750	375,407	65.7	10,442,550	746,738	101.8
1977	7,779,150	498,372	62.8	11,943,600	893,605	101.2
1978	6,367,700	408,950	58.8	10,665,500	818,692	95.4
1979	7,329,510	495,476	64.3	11,844,900	966,060	100.3
1980	6,210,590	378,853	63.6	10,166,240	807,367	99.1
1981	5,716,130	385,632	59.3	9,796,900	846,759	93.5
1982	7,298,990	522,422	60.1	11,179,590	909,738	92.5
1983	7,024,800	480,926	60.9	10,270,050	800,600	94.1
1984	7,681,160	517,488	68.5	12,013,020	1,015,042	101.4
1985	7,177,130	475,709	63.2	11,791,860	1,023,933	98.7
1986	7,398,470	472,927	63.6	11,621,740	928,191	98.1
1987	7,607,690	449,503	65.2	12,235,130	942,046	98.2
1988	7,409,920	449,797	61.3	11,383,320	898,857	94.8
1989	9,484,470	657,284	69.4	14,450,860	1,256,975	102.0
1990	10,355,260	702,367	70.0	15,456,140	1,333,124	104.3

Source:United States Department of Agriculture, Economic Research Service. Vegetables and Specialties Situation and Outlook Yearbook, TVS-255, December 1991.

[a] Includes snap beans, sweet corn, sweet peas, cucumber pickles and tomatoes. Does not include cucumbers in production or value for 1982 and 1983.

the chances of improving incomes from traditional cattle and grain crops had declined. Their survey revealed several problems that farmers faced. These problems included inadequate markets and lack of agribusiness firms. They considered these markets and firms to be crucial in improving agriculture and relieving cash flow problems in the agricultural sector by providing off-farm employment opportunities.

Vegetable production in the area has been encouraged by the findings of research conducted by the Horticulture and Landscape Architecture Department at Oklahoma State University. Vegetable trial reports indicate that climatic conditions are suitable for vegetable production (Oklahoma State University, 1987). With the increased interest in vegetable growing, questions about the possibilities of establishing a vegetable processing industry arise. Tomatoes, which have been processed in Oklahoma, are being considered as a potential crop for processing due to the higher returns associated with the crop. However, changes in temperatures, recognized as the most important factor influencing tomato growth and yield, can cause high variability in tomato yields (McCraw, et al., 1987; University of California, 1985; and Logan and Boyland, 1983). This variability can have a large impact on the flow of raw tomatoes to the processing firm, processing costs, and profitability of the processing firm.

Objectives

The overall objective of this study is to provide tools for analyzing the costs and risks of processing tomatoes in Oklahoma.

Specific objectives include:
1. Constructing an annual planning simulation model for a tomato processing firm operating in an environment of stochastic temperatures and yields anticipated in Oklahoma.
2. Finding the least cost operation plan to meet an assumed combination of processed tomato products given that tomato yields and processing operation costs are stochastic.
3. Estimating total revenues and total costs of processing.
4. Analyzing the impact of the stochastic processing costs on the firm's expected profits.

Study Area

Haskell, Hughes, Pittsburg, and Le Flore Counties included in the study by Williams and Badger and McIntosh, Muskogee, and Sequoyah Counties of east central Oklahoma (striped area in Figure 1) are chosen as the study area due to their location along the Arkansas and Canadian Rivers. Processing tomatoes have been produced in this area in the past. The area has both favorable soils in the river valleys and climatic conditions suitable for growing vegetables.

Agricultural Resources in the Study Area

According to the 1987 Census of Agriculture, farmland for the seven counties of the region was 2,272,072 acres, comprising about 56 percent of the total land area of the counties. In 1982, the number of farms in the region was 7,868 with an average farm size of 293.8 acres. In 1987, the number of farms decreased to 7,793, and the average farm size declined to 291.6 acres. In 1987, total cropland was estimated to be 847,623 acres

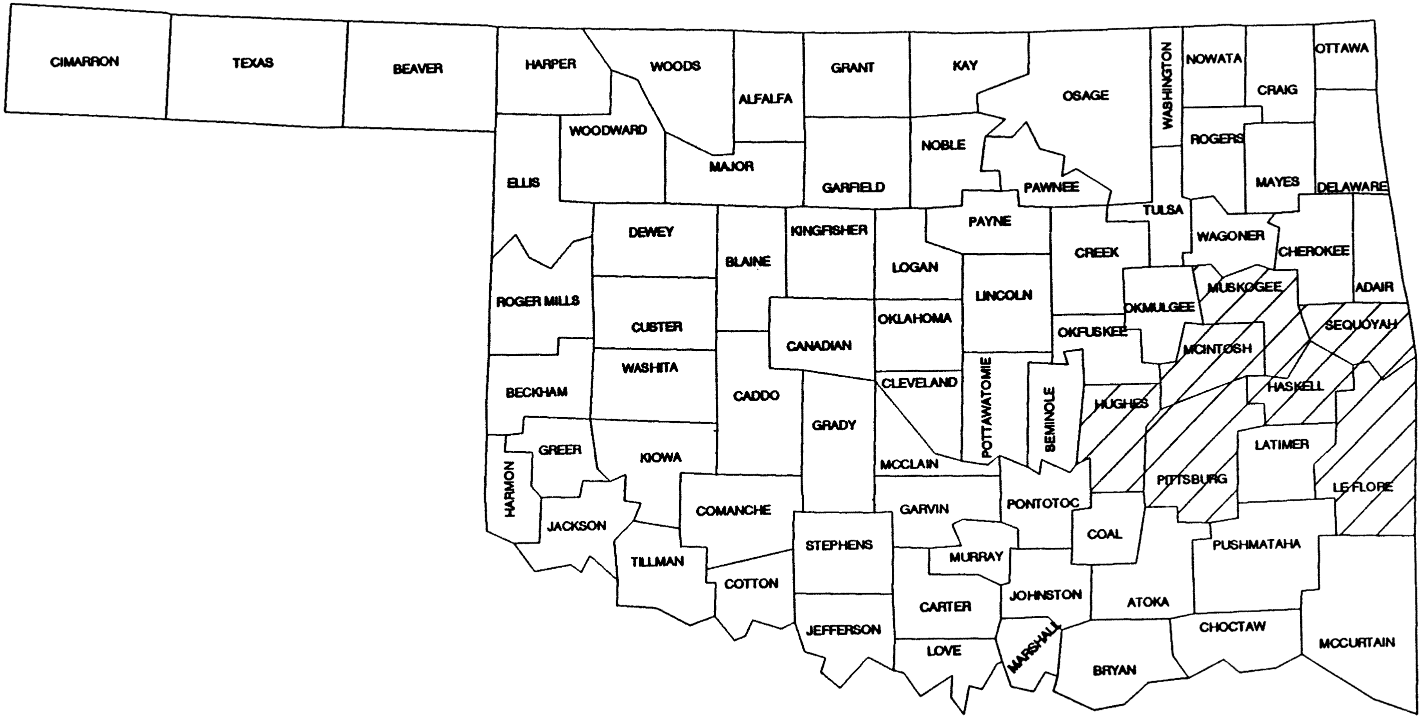

Figure 1. Study area.

or about 37.3 percent of the land in farms. Of the acres used for cropland, nearly 51 percent was used for pasture. The total acres of vegetables harvested in the region were 7,892 in 1987, comprising about 41.6 percent of the state's total.

Tomatoes are grown when the season is warm. Hot or cool temperatures will not permit economical yields. Frosts, diseases, and other environmental factors influence tomato yields and can generate great fluctuations of both the quality and quantity of tomatoes produced. Processing characteristics of the tomato fruits may be reduced or even destroyed. Yield variability caused by uncertain weather conditions has a large impact on the costs of production and the costs of the firm's processing operations. When the weather is favorable, yields are high, and the firm operates at full capacity for a period of time. On the other hand, when unfavorable weather occurs, yields are low, and the processing operations slow down. If the weather causes non-economical yields of tomatoes, the processing firms may temporarily stop. The uncertain business environment created by unpredictable changes in weather conditions can have a large impact on the successful operation of the processing firm. In this application, only the effect of uncertainties created by changes in temperature are considered.

Logan (1984) developed an annual planning simulation model for a California processing firm. The design of the model is based on the operating specification for an existing tomato processing firm with a specified number of processing lines and fixed combinations of possible final products. The model generates weekly processing operation schedules and costs over the processing season. Given the projected arrival of raw product for each week, the model determines the quantity to be processed and the number of days to be worked. It selects the minimum cost combination of processing lines among several feasible combinations. The model is also designed to predict planting dates using the concept of heat unit given the starting date of the processing operations.

Model Development

The first objective of this study is to develop a stochastic simulation planning model that projects the costs of processing tomatoes in Oklahoma. The model is then used to analyze the effect of stochastic temperatures on tomato yields which in turn influence processing firm operation and costs.

Tomato processing requires that the manager's knowledge go beyond firm operations to include tomato growing operations. Careful study of the environmental factors affecting tomato plant growth and the relationship between growing and processing tomatoes allows the manager to better plan for the upcoming processing season.

Processing Firm Operations

In general, most tomato processing firms perform the same functions with slight differences in the type of final products produced and production capacities. A processing tomato firm's operations consist of several common steps as defined by Logan (1984). The first step, after unloading the raw product, is washing and distributing the raw product to either whole tomato processing or processed tomato product processing. Tomatoes are then inspected and sorted for qualification standards for whole or processed products. Those meeting required standards are routed to their processing units, and those failing to meet the standards are disposed. Tomatoes allocated to processed products are crushed, evaporated, manufactured into paste or sauce, and sent to the appropriate units. Tomatoes allocated to whole tomato processing, after undergoing further inspection for color and texture, are routed to processing lines for whole tomato canning. In the final step, whole and processed canned tomatoes are cooked, and the cans are inspected, cooled, and routed to the warehouses. Logan classified these steps into ten stages with several types of work performed at each stage.

The Simulation Model

A stochastic simulation model based on Logan's model is developed and used to analyze the effect of stochastic tomato yields caused by unpredictable temperature variation on the costs of processing tomatoes. The model is designed to develop weekly operating schedules and costs for a tomato processing plant and select the minimum cost of producing a specific mix of final products. The model is also designed to generate random tomato yields and predicts planting dates for the raw products based on the heat unit concept.

The basic structure of the model is depicted by the flow chart of Figure 2, and is composed of the following basic components.

Component 1: The model begins by reading and calculating the input data which do not change during the simulation process: acreages used to produce the raw product, percentage of the annual quantities of tomatoes allocated to various final products, beginning and ending of the planting season, can costs and sizes, carton costs, utility costs, and wages for different labor classes used in the different stages of the production process.

Component 2: This part of the model consists of a multi-week simulation loop within which stochastic random values for the key input variables are drawn from specified distributions. Within each iteration of the week, a subroutine is called to generate random daily minimum and maximum temperatures from a multivariate empirical probability distribution. The temperatures are used by the model to predict weekly

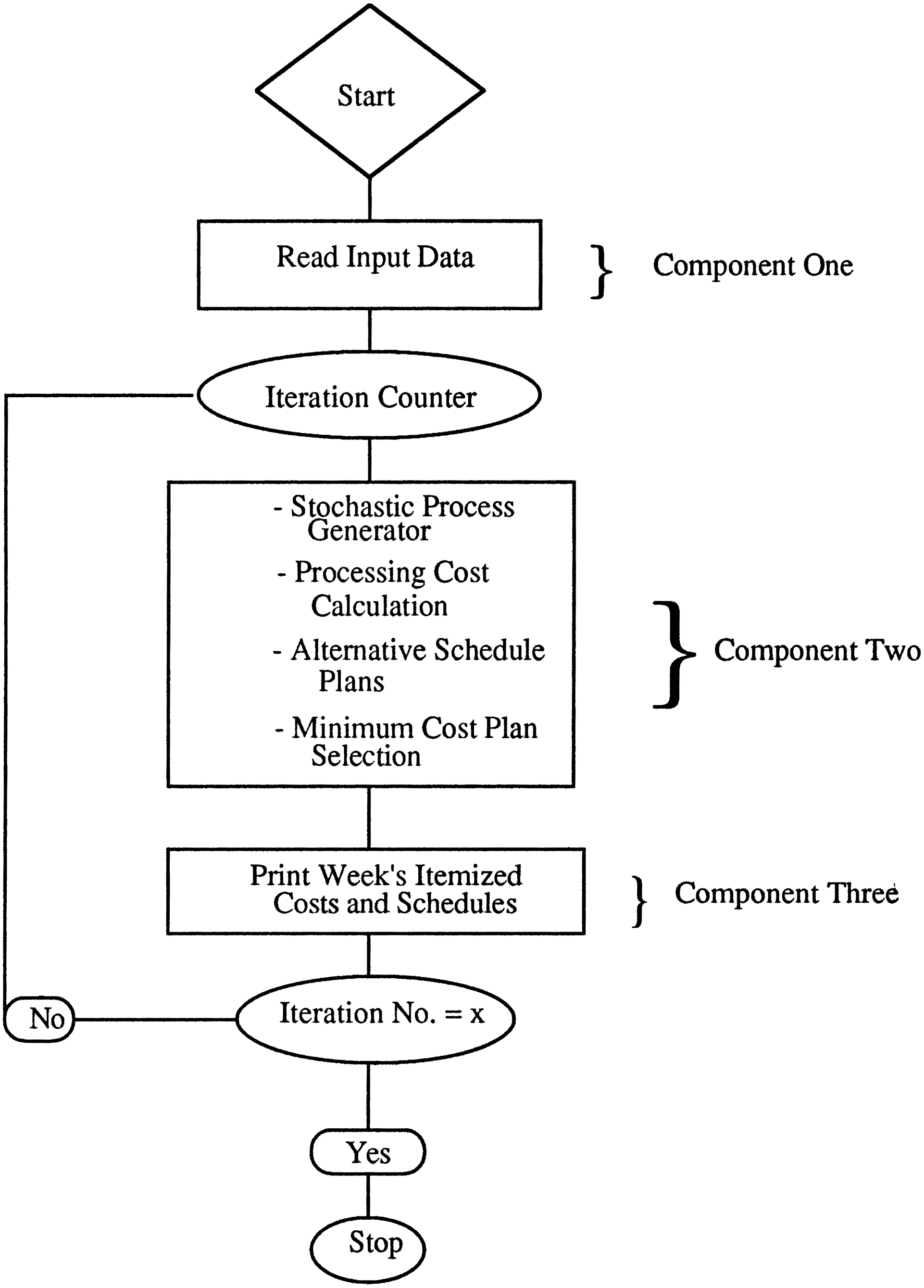

Figure 2. Flow Chart of the Simulation Model.

tomato yields conditional on the average daily temperatures occurring over the tomato's fruit set period. The quantities to be processed each week of the season, the number of days worked, and the planting dates are also determined in this component. In the final step of this component, the model finds the feasible processing combinations, the costs associated with each combination, and selects the minimum cost alternative as the week's planned schedule.

Component 3: The third and final component of the model prints the weekly total yields of raw product, daily whole and processed tomato products, and a table showing the feasible processing combinations, along with their costs and the number of shifts required. The selected minimum cost combination is also printed as well as the number of employees per shift, the raw product equivalent of processed production, and the cases produced each week by each canning line. Summary tables for each week and the whole season's itemized costs are also printed in this component.

Non-Variable Input Data

Non-variable input data are either read in the first component or defined directly in the model. They include: processing lines for different types of products, capacity of each line in cases of final products, and the case conversion coefficient for each processing line to convert a case of final product into pounds of raw product. For each canning line, Table 2 illustrates the product produced, can size used, output capacity, cans per case, and the pounds of raw product per case.

The processing firm is assumed to consist of twelve independent canning lines which can produce whole peeled tomatoes, paste, and sauce with a rated capacity of 185 tons per hour when all the lines are in operation. These twelve lines are described in Table 2. The first group consists of lines 1 through 7 which can produce only whole peeled tomatoes in No. 303 cans for the first three lines, in No. 10 cans for lines 4 and 5, and in No. 2-1/2 cans for lines 6 and 7. These seven lines have a combined capacity of 61 tons per hour. The second group produces only paste in 12 oz. cans on line 10 and 6 oz. cans on line 9 and line 11. The third group consists of line 8 with No. 10 cans and line 12 with No. 2-1/2 cans which produce sauce or paste. Sauce is produced if the season's output requirement for sauce has not been met to date. Otherwise, paste is produced. The combined rated capacity of lines 8 through 12 is 129 tons per hour when they are used to produce paste only and 124 tons per hour when both paste and sauce are produced. The capacity of the processing unit increases from 185 to 189 tons per hour when the lines are producing whole tomatoes and paste. For computation purposes, lines 8 through 12 are renumbered as lines 13 through 17 when they are used to produce paste only.

Table 2. Product, Can Size, Capacity, Number of Cans Per Case, and Pounds of Raw Product Per Case by Line.

Canning line[a]	Product Produced	Can Size	Capacity	Cans per Case	Raw Product Requirement
			Cases/hr		lbs/Case
1	whole	303	350	24	36.360
2	whole	303	450	24	36.360
3	whole (stewed)	303	550	24	36.360
4	whole	10	200	6	58.940
5	whole	10	400	6	58.940
6	whole	2-1/2	140	24	64.175
7	whole	2-1/2	450	24	64.175
8	sauce	10	420	6	129.680
8	paste	10	350	6	231.576
9	paste	6 oz.	430	48	102.859
10	paste	12 oz.	500	24	124.431
11	paste	6 oz.	430	48	102.859
12	sauce	2-1/2	300	24	141.200
12	paste	2-1/2	125	24	252.148

[a] Canning lines 8 and 12 can produce sauce or paste.

Source: Logan (1984) and Brandt and French (1981).

The capacity (CAP) per hour shown in Table 2 is for a 100 percent operation efficiency for each line. In the model, this capacity is multiplied by .7 to allow for down time caused by equipment breakdown and other stoppages.

The amount of labor required for tomato processing is determined by the operation stages and the number of employees needed to perform a particular job in each stage. To operate the first whole tomato line (line 1), 185 employees are required per eight-hour shift. Each additional whole tomato line requires three or four additional employees. To operate all seven whole tomato lines requires 205 employees. To operate one processed product line at the same time as the whole tomato lines requires an additional 24 employees, two processed product lines requires 25, three lines 26, four lines 28, and five lines 30. The processed product lines can operate additional shifts without the whole tomato lines operating. To operate only one processed line during a shift requires 82 employees. Each additional line requires an additional employee. At full capacity operation of all the processing lines, the total number of employees required per eight-hour shift is 235. Labor requirements are provided in Appendix A, Table 19.

Labor is classified according to the type of service performed in each stage of the processing operations. Hourly wages are estimated accordingly. The same type of classifications specified by Logan are used with hourly wages updated for the McAlester area in East Central Oklahoma (Center for Economic and Management Research, 1986). Since some labor classifications are not available for the area, approximate classifications in terms of wages and occupations are used. Hourly wages for each class in each stage of the processing operations are illustrated in Appendix A, Table 20. The wages are read into the model as non-variable input data along with the number of employees in each class for each stage of the processing operations.

Production combinations show the per day maximum levels of raw products that can be processed by various combinations of processing lines and shifts worked. There are five eight-hour shift possibilities considered in the model: 1, 1.5, 2, 2.5, and 3 shifts each for whole and processed products. Three types of production combinations are defined by Logan as:

a) production combinations for processing whole tomatoes by different lines for different numbers of shifts worked per day. The number of shifts worked are assumed the same across the lines; that is, when 1, 1.5, or 2 shifts are worked on one line, the other lines use the same number of shifts. Any combination from 35 production combinations of whole tomato processed products is possible (five possible shifts x seven line possibilities per shift).
b) production combinations for processed products when lines 9, 10, and 11 are producing paste and lines 8 and 12 are producing sauce. Production combinations for these lines are estimated in the same way as above, resulting in 25 possible production combinations.
c) production combinations for processed products when lines 8 through 12 are all used to produce paste. Changing lines 8 and 12 from producing sauce to paste would result in the same production combinations as in (b) above. Since the lines can only produce one product or the other, no new production combinations are created.

The feasible combination is selected by determining the average daily output of processed products that can be produced per week. The feasible combination for each shift is defined as that production combination whose requirements of raw products is greater than or equal to the average daily output requirement of processed products (Logan, 1984). Given the number of days of operations per week and the raw product equivalent of processed products, the average daily output of processed products can be determined. With the assumption that the proportions of raw products devoted to processed products are greater than those for whole tomato products, the number of shifts worked on processed products lines are always greater than the number of shifts worked on whole tomato product lines. Therefore, combining production combinations for whole and processed products, there would be 25 feasible production combinations. Furthermore, the possible combinations in which the number of shifts worked for whole tomatoes are greater than the number of shifts worked for processed products can be disregarded, and 15 feasible production combinations remain as illustrated in Table 3.

Another feasible production combination is added when employees are allowed to work for seven days with all lines operating during three shifts for both processed and whole tomatoes. This combination is considered only when the expected raw products cannot be processed in six days with three shifts per day. The excess raw product is carried over to the next week if this option is not sufficient. Thus, there are 16 feasible production combinations considered in the model which, in turn, determine the production cost combinations available to the model.

Generally, the tomato processing industry is characterized by a grower-processor contractual agreement promoted by several types of uncertainties in the market. One important factor leading to contractual agreements is uncertain future prices when the processing season begins. Contracts are usually made prior to the start of the planting season to reduce the magnitude of future price risk. Prices are assumed to be established under contractual agreements which will prevail through the processing season with premiums paid for early and late season deliveries.

To estimate costs of growing the crop in the study area, a processing tomato budget was developed and is provided in Appendix B. Twenty percent of the per ton cost was assumed as a reasonable amount to cover the return to the grower's management, overhead, handling costs, and risk. One hundred and twenty percent of the per ton cost ($65.54) is used in the model as the accrued cost per ton to the processing firm.

Table 3. Feasible Production Combinations for Whole and Processed Tomato Products.

Shifts for Processed Products			Shifts for Whole Products		
	1	1.5	2	2.5	3
1	1,1	1,1.5	1,2	1,2.5	1,3
1.5		1.5,1.5	1.5,2	1.5,2.5	1.5,3
2			2,2	2,2.5	2,3
2.5				2.5,2.5	2.5,3
3					3,3

The amount of various forms of processed products to be processed during the season depends on the expected market conditions and the contractual agreements made by the firm. Per case processor prices for processed tomato products published in the Reports on Food Market (American Institute of Food Distribution) and Vegetables Situation and Outlook (United States Department of Agriculture) are used to derive the firm's total revenues and are shown in Table 4 for the various forms of final products.

Since data are not available to specify the harvesting dates for the tomato crop during the processing season, the growing season is assumed to begin on March 1st and end before December 1st, thereby avoiding severe weather conditions during the remaining months. The processing season is contained in this period, and the earliest possible harvest date is decided upon by running the model several times for alternative harvest dates. The harvest date that produces the earliest possible planting date after March 1st is selected and is found to be the 120th day of the planting season which corresponds to June 28th.

Another set of non-variable input data consists of the acres to be planted and the proportions of raw products allocated to whole tomato processing, paste, and sauce.

Variable Input Data

A major part of the cost incurred in the processing operation is the utility cost. Electricity, natural gas, and water requirements by the processing firm are derived on the basis of the physical units used per ton

Table 4. Processed Tomato Product Prices.

Product	Can Size	Product Price/Case
		($)
Whole	303	8.00
Whole (stewed)	303	9.50
Whole	10	10.50
Whole	2 1/2	12.50
Sauce	10	10.25
Sauce	2 1/2	12.50
Paste	10	20.00
Paste	2 1/2	24.00
Paste	6 Oz	12.00

Sources: American Institute of Food Distributions, Reports on Food Market, different issues 1987-88. United States Department of Agriculture, Vegetables Situation and Outlook, different issues 1987-88.

Table 5. Utility Requirements Per Ton of Raw Product by Type of Processed Products.

Final Product	Electricity	Natural gas	Water
Tomatoes	Kwh/ton	therms/ton	gal/ton
Whole	42.532	17.553	946.284
Sauce	10.008	25.101	946.284
Paste	10.008	18.431	946.284

Source: Logan, 1984, p. 10; Stillwater Electric Utility, Stillwater, Oklahoma; and Oklahoma Natural Gas Company.

of raw product processed into whole or processed products. These requirements are estimated by Logan as shown in Table 5. Costs of utilities based on Oklahoma rates are estimated at $.068 per kwh for electricity, $.67 per therm for natural gas, and $.00165 per gallon for water.

When any of the processed paste processing lines are closed or less than three shifts are worked per day, evaporator clean-up costs are incurred. If three shifts are worked per day, evaporator clean-up costs are incurred only once per week or less. The processing lines must be cleaned and made ready for the next use whenever they stop processing. One evaporator is used for each of the five paste lines.

Boilers are used for hot water. Hot water is needed for the production of sauce or paste. Two boilers with the capacity of 80,000 and 120,000 pounds are used in this model. When less than three shifts per day are worked, the boilers must be reheated for the next operation. The estimated per service evaporator clean-up and boiler costs for different combinations of the processing lines, where the requirements for lines 8, 9, and 10 are assumed to be met by the larger boiler and lines 11 and 12 are met by the smaller, are given in Table 6. Logan obtained the chemical compound costs per evaporator clean-up and boiler start-up service from industry sources. In this application, the boiler start-up costs are assumed to be estimated on the basis of the natural gas costs. Thus, Logan's estimates are divided by the per therm cost of natural gas to obtain the amount of therms and then multiplied by the per therm cost rate for Oklahoma. The per unit costs are defined directly in the model from which the weekly costs are derived.

Another set of input data included in this category consists of the number of cans per case of final product based on can size, can cost, cost of cartons needed to pack the final products, and costs of lye and salt required for whole tomato processing. The per unit cost of these items are shown in Table 7. Salt requirements are calculated on the basis of the amount of tablets needed per case of final product.

Table 6. Clean-up and Boiler Start-up Costs Per Occurrence.

Line	Boiler Start-up	Evaporator Clean-up	Total
	$	$	$
8	2,000	300	2,300
8,9	2,000	600	2,600
8,9,10	2,000	900	2,900
8,9,10,11	3,340	1,200	4,540
8,9,10,11,12	3,340	1,500	4,840

Source: Logan, 1984, p. 11.

Table 7. Number of Cans, Can and Case Cost, Carton Cost, and Number and Cost of Salt Tablets.

Can Size	Cans/ case	Cost/can	Cost/ case	Cost/ carton	Salt	Cost/ tablets
	No.	$	$	$	Tablets	$
303	24	0.100	2.40	0.178	24	0.0030
303 (stewed)	24	0.100	2.40	0.178	24	0.0022
2-1/2	24	0.175	4.20	0.265	24	0.0053
10	6	0.500	3.00	0.225	12	0.0099
6 oz.	48	0.085	4.08	0.143		
12 oz.	24	0.120	2.88	0.138		

Source: American Can Association, 1988 and Logan, 1984, p. 11.

Stochastic Variables

Stochastically estimated daily maximum and minimum temperatures are generated from a multivariate empirical probability distribution. These temperatures are then used to estimate the duration of the fruit set period and the planting date of the tomato transplant. Stochastic tomato yields are generated conditional on the average daily temperatures occurring over the fruit set period.

Temperatures

Temperature variations have a significant influence on the fruit set stage of development, the crucial period for determining yield. Daily maximum and minimum temperatures for 33 years, 1954 through 1986, for the McCurtain area (Haskell County) were obtained from Oklahoma Climatological Data (U.S. Dept. of Commerce). January, February, and December are excluded to avoid severe cold weather which may not permit planting or growing tomatoes. Given that some data prior to 1954 are not reported, the 33 years of data are assumed sufficient to provide daily maximum and minimum temperatures distributions. Multivariate empirical distribution functions are estimated using the 33 years of historical data.

Clements et al. (1971) developed a procedure for correlating normally distributed events in simulation models. Richardson and Condra (1978) later modified the procedure into a general procedure which can be used to generate correlated random variables from different distributions. Following their work, the first step in using the procedure to generate stochastic random temperatures from the multivariate empirical distribution is to calculate the correlation coefficient matrix from the historical data. Using the square-root method, the matrix is factored into an upper triangular matrix. The next step in developing the distributions is to compute the deviations from the mean values for the daily maximum and minimum temperatures for each of the 33 daily temperatures, and then rank the deviations in increasing order (Richardson and Condra, 1978; Law and Kelton, 1982). A FORTRAN computer program is used to estimate the unique upper triangular matrix and the ordered deviations, and the output was stored for later use. The third step is to generate a vector of independent standard normal deviates. A random normal deviate generator [RANF(IX)] obtained from the Computer Center at Oklahoma State University is used to generate the deviations. The next step is to generate a vector of correlated pseudo-random numbers distributed standard normal using

$$C = RW$$

where R is the factored correlation matrix and W is the vector of independent random normal deviates. The C vector is then transformed into a vector of pseudo-random numbers distributed uniformly on the scale of zero to one. The transformation equation can be written as

$$U = 0.5 + [0.5\ \mathrm{ERF}(\frac{C}{\sqrt{2}})]$$

where U is a vector of pseudo-random numbers distributed uniformly (0,1), and ERF is an IBM supplied function for integrating the area under the standard normal probability function of its random deviate C. The values obtained for the U vector are used to generate the cumulative distribution functions for the random variables by the use of the inverse cumulative distribution functions transformation method (Law and Kelton, 1982; Meier et al., 1969; Guiterrez, 1985). For the variable of interest, say Y, the method involves taking the cumulative distribution function, say F(Y), and setting it equal to the uniformly distributed random value U. The equation is then solved for Y to obtain the inverse function $Y = F^{-1}(U)$. Each time a value for U is substituted into $F^{-1}(U)$, a corresponding value for Y is obtained. Graphically, this method is illustrated in Figure 3 for the one variable case, where, y_1 and y_2 are projected by their respective uniform random values U_1 and U_2.

Richardson and Condra presented a mathematical formula to generate random values from the empirical distribution for the three internal cases:

$$
\begin{array}{ll}
Y_i = a + (b-a)(U_i) & , 0 \le U_i \le P_1 \\
Y_i = b + (c-b)\left(\dfrac{U_i-P_1}{P_2-P_1}\right) & , P_1 \le U_i \le P_2 \\
Y_i = c + (d-c)\left(\dfrac{U_i-P_2}{1-P_2}\right) & , P_2 \le U_i \le 1 \\
\text{for } a < b < c < d & , a < Y_i < d
\end{array}
$$

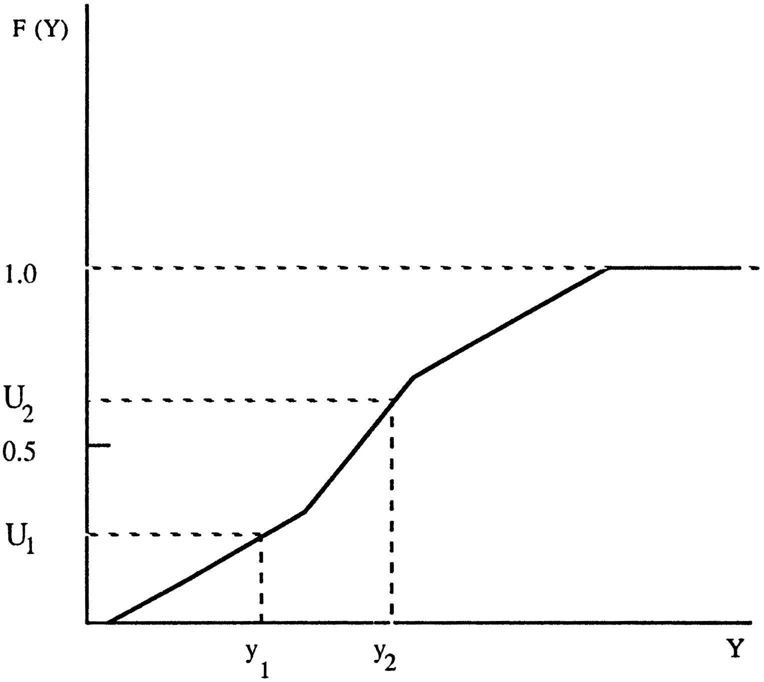

Figure 3. Graphical Illustration for Drawing Random Values from the Cumulative Distribution.

where U_i is a uniformly distributed random number over the interval zero to one; a, b, c, and d represent the values of Y_i at which the slope of the cumulative distribution function for Y changes; and P_1 and P_2 represent the probabilities.

A modified version of Richardson and Condra's FORTRAN computer program for drawing random numbers from a cumulative distribution function was used in the model as a subroutine to generate stochastic temperatures. Each time the iteration loop is used the subroutine is called, and a random maximum and a random minimum temperature is generated.

Data for yields of processing tomato plants are not available from Oklahoma. Using historical data from other states or the U.S. average yields implicitly assume that the climatic conditions in Oklahoma are similar to those states and that the yield distributions of the past years are the same as the future distributions. The probability distributions of economic variables change over time in the real world, and the decision-maker is faced with uncertain outcomes from which he must form expectations (McSweeny et al., 1987). Accepting this view, an estimation procedure to predict tomato yields conditional on the average daily temperatures occurring over the crucial stage of development of the tomato plant was developed in this study.

The first step of the procedure is to specify the crucial stage in tomato plant development at which unfavorable temperatures will have the most influential impact on yields. Tomatoes pass through several stages of growth during the season. Seedling stage, vegetative stage, flowering stage, fruit setting, and maturity stages all require a certain amount of heat units to develop. The rate of plant growth is determined primarily by the level of temperature to which the tomato plant is exposed. Plant growth increases rapidly as temperature increases above a certain minimum threshold, then plant growth increases at a decreasing rate to an upper limit beyond which growth declines (University of California, 1983; Logan and Boyland, 1983; Owens and Moore, 1974). Excessively high or low temperatures may have a negative effect on the plant growth stages causing delay of development or plant retardation. Temperatures above 94°F or temperatures below 60°F will not permit flowers to set fruits for economical yields (McCraw et al., 1987). The fruit setting stage is recognized by Motes (1988) as a very critical stage of the plant development during which changes in temperatures will have the most important impact on yields. The fruit set stage is considered the crucial stage which provides essential information to estimate the yields.

The second step in the estimation procedure is to determine the number of days elapsed during the fruit set stage. Bush processing tomato varieties can be harvested mechanically in a single pick because bush processing tomato varieties produce flowers and set fruits in a relatively short period (University of California, 1983). Fruit set is expected to be relatively uniform which suggests a consistent fruit set interval among plants planted at the same time.

To determine the length of time for a particular growth stage, an estimate of the effective heat units used by the tomato plant to complete that stage is required. Heat units is a mechanism used to measure the effective heat units required by the plants to develop. Heat units refers to the amount of effective heat units that accumulate during a 24-hour period when the average daily temperature is one degree above the developmental threshold (University of California, 1983).

Several methods are available to calculate heat units. The sine function method determines the heat units accumulated during a 24-hour period by integrating the sine function between the minimum temperature in day one to the minimum temperature in day two in a 24-hour period. This method was developed by Logan and Boyland to increase the precision of calculating the heat units by approximating the behavior of temperatures occurring during the day. Logan and Boyland employed the sine function and the approximate mean methods to calculate the mean amount of heat units required by the processing tomato plant from first day of planting to the first day of harvest using planting and harvesting dates from four major commercial locations in California. They argued that the results obtained by the sine function, presented in Table 8, were less dispersed compared to the approximate mean method and perform more consistently on the average.

Owens and Moore (1974) employed four methods — the approximate mean, the exact mean, the corrected mean, and the median minus base — to estimate heat units requirements by the tomato plant cultivar "Chico" from the time of seeding to the time of 75 percent maturity at Scott, Mississippi. The results showed a significant difference in the mean amount of heat units required by the cultivar among the methods tested. The mean heat units varied from 1,462 with a base temperature of 55°F and a ceiling temperature of 80°F using the corrected mean procedure to 3,932 heat units with a base of 40°F and no ceiling temperature using the approximate mean method. Their findings indicate that the amount of heat units obtained depends on the minimum temperature used as a base, the maximum temperature used as a ceiling, and the method used. They suggested that the most precise method was the corrected mean when using a ceiling temperature of 80°F and a base of 40°F. The mean amount of heat units required by the cultivar using this method at first flower was 1,142, at 65 percent fruit maturity was 3,028, and 75 percent fruit maturity of growth stages was 3,236. Table 9 illustrates heat units requirements by the Chico cultivar from seeding to various stages of growth obtained by the corrected mean method.

Even though the sine function method is considered a better procedure, the corrected mean method was used to estimate the number of days needed to obtain the required heat units. The corrected mean method was chosen because of the results reported by Owens and Moore

Table 8. Estimated Heat Unit Requirement for Tomatoes at Four Major Locations in California for Two Different Estimation Methods.

Location	Sine Function			Approximate Mean		
	Heat Unit Mean	Standard Deviation	Coefficient of Variation	Heat Unit Mean	Standard Deviation	Coefficent of Variation
	(C° -days)			(C° -days)		
Davis (n=32)	1,742	144	0.0826	1,914	184	0.0961
Clarksburg (n=15)	1,819	132	0.0725	1,960	147	0.0750
Winters (n=14)	1,871	117	0.0625	2,114	154	0.0728
Woodland (n=24)	1,836	158	0.0862	2,094	200	0.0955

Source: Logan and Boyland,1983.

Table 9. Heat Unit Requirements by the Chico Processing Tomato Cultivar at Scott, Mississippi, from Seeding to Various Stages of Growth with 80°F Ceiling and 40°F Base Temperature.

Stage of Growth	Planting Dates 3/31	4/20	5/10	5/19	Mean of 4 Dates	Coefficient of Variation	Day Range
Cotyledon expansion	360	434	372	357	380	9.59	2.6
First Leaf	503	555	482	448	497	9.02	3.6
Third Leaf	622	684	666	598	642	6.14	2.9
First Flower	1,329	1,158	1,013	1,066	1,142	12.14	10.1
65% Maturity	3,038	2,990	3,018	3,068	3,028	1.08	2.6
75% Maturity	3,327	3,167	3,272	3,276	3,236	1.57	3.6

Source: Owens and Moore, 1974, p. 6.

for several growth stages and the similar plant growing conditions between their study area and those of Southeastern Oklahoma.

The mean amount of heat units required by the plant during the first flower through 65 percent of fruit maturity was estimated as 1,886 by Owens and Moore using the corrected mean method for the Chico cultivar. Under the conditions of limited data available for the study, the amount of heat units used by the plant from the establishment of first flower to 10 percent maturity was assumed as an approximate measure for the duration of the fruit set stage.

The final step of the procedure is to obtain an expected tomato yield conditional on the estimated average daily temperatures over the fruit set stage. In the absence of data, triangular probability distributions for economic events are used by many researchers in simulation models because they are easy to estimate and do not require the tedious probability estimations involved in eliciting other distributions. The triangular probability distribution can be completely identified by the minimum, maximum, and most likely value of the variable of interest as shown in Figure 4.

Triangular probability distributions are used to generate stochastic tomato yields conditioned on the average daily temperatures occurring over the fruit set stage period. The minimum, maximum, and modal values for tomato yields were obtained for the study area from experts in the Horticulture Department at Oklahoma State University and are shown in Table 10 (Motes, 1988).

Under an average daily temperature of 70°F to 80°F, the most likely yield was assessed at 20 tons/acre. A 40 to 60 percent reduction in yield is expected if the average daily temperature drops to the 65-69.9°F

Table 10. Processing Tomato Yield Assessments.

Average temperature range during the fruit set stage	Most Likely (Modal)	Maximum Yield	Minimum Yield
°F	tons/acre	tons/acre	tons/acre
60-64.9	0	0	0
65-69.9	10	12	8
70-74.9	20	24	15
75-79.9	20	25	15
80-84.9	16	18	12
85-89.9	10	12.5	7.5
90-Over	0	0	0

Source: Motes, 1988.

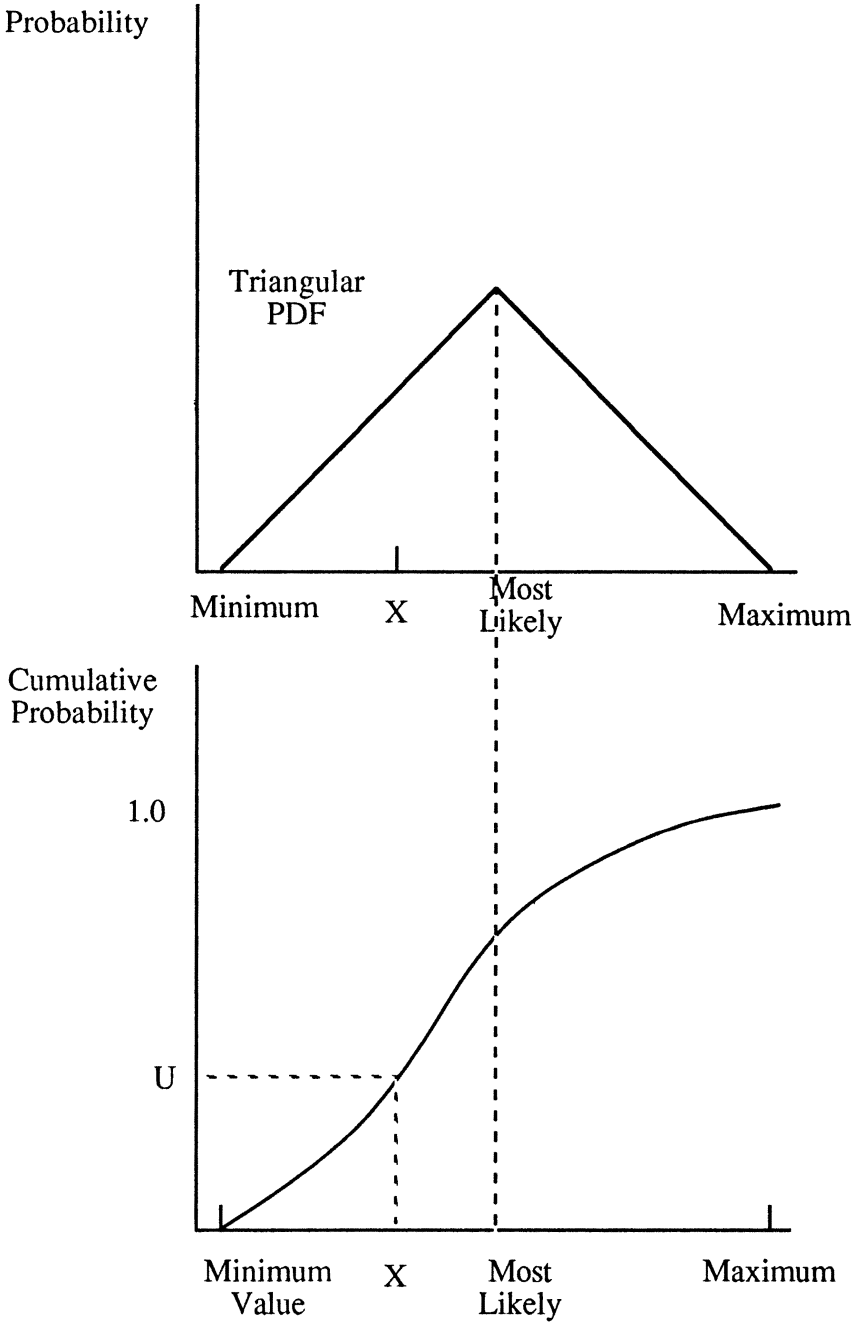

Figure 4. Graphical Illustration of Generating Random Variable X which has a Triangular Probability Distribution.

range. Also, an increase in the average daily temperature to 80°F-85°F also produces a 40 to 60 percent reduction in yield. When the average daily temperature drops below 65°F or rises above 90°F, the tomato plant is not expected to set fruits.

To generate the stochastic random yields a FORTRAN subroutine, RANF(IX), is called within each iteration of the simulation loop to draw random normal deviates. The deviates are then transformed into a uniform zero to one distribution by the following equation

$$U = 0.5 + [0.5 * \mathrm{ERF}(\frac{D}{\sqrt{2}})]$$

where U is a uniform random value distributed (0, 1) and ERF is the error function to integrate the area under the standard normal density function for the deviate D.

Next, the obtained U values are used in the inverse transformation function to project the corresponding yield values. The triangular cumulative distribution function as presented by Sprow (1967) can be written as

$$\begin{aligned} F(x) &= (x - a)^2/[(b-a)(m-a)], \quad a \le x \le m \\ &= 1-(b-x)^2/[(b-a)(b-m)], \quad m \le x \le b \end{aligned}$$

where, X is the random variable, a is the minimum, m is the most likely value, and b is the maximum value.

Equating F(x) to the uniform variate U and solving the above equations for x, the value left of the mode, x_L and the value right of the mode, x_R can be derived,

$$\begin{aligned} X_L &= a+[U(b-a)(m-a)]^{.5}, \qquad && 0 \le U \le (m-a)/(b-a) \\ X_R &= b-[(1-U)(b-a)(b-m)]^{.5}, \qquad && (m-a)/(b-a) \le U \le 1 \end{aligned}$$

Annualized Costs

To determine expected profits for the processing firm, equipment and construction costs were obtained through written and phone call requests to several manufacturing and professional sources, and from Snyder et al. (1988). The costs of processing lines (based on can size and raw product capacity) and all necessary equipment for handling empty cans, filling operations, and full can warehouse departments were provided by Richard Gomez of Custom Food Machinery Inc., California. These costs are shown in Table 11. Building costs were estimated on the basis of the area needed per processing line and the construction cost per square foot. Investment requirements for the processing facility as well as the annualized costs, are shown in Table 12. Equipment is amortized for 15 years, buildings for 20 years, and land for 40 years at 10 percent. Start-up costs are incurred during the construction period prior to start of the processing operations, and include management costs, travel, employee recruitments, and professional services. Annual management salaries include salaries for the general manager, production manager, procurement manager, sales manager, fieldman, and 20 percent fringe benefits. Building cost for the processing center is estimated at $50 per square foot, while warehouse building cost is estimated at $20 per square foot.

Model Validation

The model was investigated by verification and validation processes to test the degree of the model's credibility in simulating the actual system. A model which represents a system for which no actual data are available can be validated by performing a rigorous examination of the model structure (Meier et al., and Mihram, 1972). Verification was conducted during both the construction stages of the model and after the model had been developed.

Table 11. Costs of Processing Lines for the Proposed Processing Facility.

Line	Product	Can Size	Capacity, Raw Product	Cost	Annualized Cost
			Tons/hr	$	$
1	Whole	#303	6.365	520,000	68,380
2	Whole	#303	8.18	520,000	68,380
3	Whole (stewed)	#303	10.00	520,000	68,380
4	Whole	#10	5.9	560,000	73,640
5	Whole	#10	11.80	560,000	73,640
6	Whole	#2 1/2	4.50	520,000	68,380
7	Whole	#2 1/2	14.43	520,000	68,380
8	Sauce	#10	27.23	650,000	85,475
9	Paste	6 oz.	21.11	425,000	55,888
10	Paste	12 oz.	31.10	425,000	55,888
11	Paste	6 oz.	21.11	425,000	55,888
12	Sauce	#2 1/2	21.18	520,000	68,380

Source: Gomez, 1988.

Table 12. Investment Requirements and Associated Costs

Item	Cost	Annualized Cost
	$	$
Processing Lines	6,165,000	810,698
Buildings		
Offices	650,000	85,475
Processing Center	39,000,000	4,582,500
Paving	550,000	64,625
Warehouse	1,444,500	169,729
Additional Facilities		
Boiler Room	250,000	32,850
Shop & Lab Equipments	290,000	38,106
Land (30 acres)	30,000	3,069
Waste Disposal System	750,000	98,550
Other		
Management Salaries		234,000
Start-up Capital	445,000	58,473
Equipment Installation	850,000	111,690
Contingency (10%)	5,042,400	662,570
TOTAL	55,466,900	6,887,710

Important aspects of model verification when stochastic processes are considered in the simulation model are the distributions of the variables intended to have random behavior. The selection of the seeds for random number generation on which the randomness process is based should be random and independent from one another. In this study, the model uses a random number generator called GAUSE, written in FORTRAN and incorporated in the model as a subroutine, to generate random numbers used as the seeds for drawing random tomato yields from triangular probabilities and random temperatures from empirical probability distributions.

Another step taken to verify the model was the investigation of its logical structure. The model was run deterministically several times and checked for syntax errors. The stochastic processes were then introduced directly or as a subroutine into the model, which facilitated easier construction and less complicated syntax.

Stochastic Temperatures

The stochastic maximum and minimum temperatures expected during a particular day of the planning season are drawn from multivariate cumulative empirical distributions using 33 observations for each

Table 13. Correlation Coefficients Between Daily Low and High Temperatures for Selected Days of the Season.

Day	Date	Correlation Coefficients	
		Actual	Simulated
60	March 1	0.753	0.706
91	April 1	0.624	0.561
121	May 1	0.390	0.302
152	June 1	0.550	0.515
182	July 1	0.548	0.476
213	August 1	0.675	0.731
244	September 1	0.531	0.450
274	October 1	0.524	0.40
305	November 1	0.753	0.709

day from 33 years of historical data for the McAlester area in Southeastern Oklahoma. The estimated correlation coefficients for the actual and simulated daily low and high temperatures obtained for selected days from 100 iterations are listed in Table 13. The actual and simulated maximum, minimum, mean, and standard deviations for the day's high and the day's low temperature for the same iterations are listed in Table 14 along with the t-statistics and the F-statistics values. The t-statistic is used to test the hypothesis that the simulated mean is equal to the actual mean and the F-statistic is used to test the hypothesis that the variance of the simulated temperatures is equal to the variance of the actual temperatures. Both the t-test and F-test are applied at the a = .05 significance level. The statistics shown in Tables 13 and 14 are selected arbitrarily as the first day of each month to limit the amount of data reported. Of the 550 variances tested only six variances failed the F-test. All of the 550 means tested passed the t-test.

Simulation Results

The simulation model was constructed on the basis of several decisions that must be made prior to the start of the processing season. These decisions include: the number of acres to be planted for the tomato crop, the starting time of the processing season, the allocation of raw product to the various forms of final products, the priority with which the final products are to be produced, the number of shifts per day, and the number of days of plant operation per week.

Table 14. Selected Statistics for the Actual and Simulated Day High and Low Temperatures.

	Maximum		Minimum		Mean		T-Statistic[a]	Standard Deviation		F-Statistic[b]
Date	Actual	Simulated	Actual	Simulated	Actual	Simulated	Means equal	Actual	Simulated	Variances equal
Day's High Temperatures °F										
March 1	78.00	78.00	25.00	25.12	59.39	61.11	-0.72	12.96	11.42	0.78
April 1	88.00	83.88	52.00	52.05	71.79	71.27	0.31	8.74	8.09	0.86
May 1	88.00	88.00	61.00	61.00	75.61	74.44	0.91	6.95	6.14	0.78
June 1	96.00	95.87	73.00	73.33	82.52	82.60	-0.09	5.32	4.67	0.77
July 1	103.00	102.93	74.00	74.52	91.12	90.40	0.63	6.25	5.49	0.77
August 1	106.00	105.92	79.00	79.21	94.15	94.38	-0.19	6.37	5.91	0.86
September 1	102.00	101.64	66.00	69.84	90.24	91.54	-0.95	7.83	6.48	0.68
October 1	96.00	95.86	63.00	63.00	80.70	80.06	0.37	8.79	8.62	0.96
November 1	82.00	81.78	51.00	51.14	69.42	68.52	0.48	9.18	9.36	1.04
Day's Low Temperatures °F										
March 1	63.00	60.47	15.00	15.84	36.55	38.25	-0.72	12.34	11.59	0.88
April 1	67.00	66.94	25.00	25.52	47.18	46.87	0.14	10.98	10.89	0.98
May 1	69.00	68.54	40.00	40.66	54.88	54.54	0.22	8.57	7.67	0.80
June 1	74.00	73.49	45.00	45.17	61.61	62.95	-0.96	7.25	6.92	0.91
July 1	79.00	78.01	62.00	62.48	71.49	70.93	0.74	3.83	3.64	0.90
August 1	77.00	76.46	61.00	61.01	70.46	70.47	-0.01	3.93	4.24	1.17
September 1	78.00	78.00	55.00	55.24	69.30	70.20	-0.85	5.70	5.15	0.82
October 1	69.00	69.01	37.00	39.55	55.46	55.77	-0.18	9.22	8.35	0.82
November 1	68.00	66.99	20.00	22.03	46.64	44.78	0.84	11.55	10.93	0.90

[a] T-Statistic used to test the hypothesis that the simulated mean of temperature is equal to the mean of the actual historical temperatures. Hypothesis accepted if T-Statistic is between -1.98 and 1.98.

[b] F-Statistic used to test the hypothesis is that the simulated variance of temperature is equal to the variance of actual historical temperatures. Hypothesis accepted if F-Statistic is between 0.59 and 1.85.

Simulation results for 100 iterations of the model were generated assuming 400, 200, and 100 acres of tomato production each week. The 400 acre plan serves as the baseline and is discussed in greater detail. The earliest date to begin processing was found to be the 120th day (June 28) of the planting season which starts on March 1. The expected raw products are allocated as 33 percent for whole tomatoes, 50.67 percent for paste, and 16.37 percent for sauce. These allocations depend on the demand for these products and the contractual agreements made by the firm with its customers. The order in which the processing lines are numbered reflects the priority with which the final products are produced as shown in Table 2, and the number of shifts are stipulated at 1, 1.5, 2, 2.5, and 3 for whole and processed products.

Processing Schedules and Costs

The results obtained from the model for a particular week are printed in table form. Weekly schedules show various feasible cost alternatives for different shifts, least cost alternative selected, processing lines used to process the raw product for that week, type and amount of final products produced by each canning line for the least cost alternative selected, total costs for each input item, average temperature expected to prevail over the fruit set period, daily average whole and processed raw products, and total costs incurred for that week. If a frost occurs during the growing season or an unfavorable daily average temperature occurs during the fruit set period, the model indicates that by printing out the week, the iteration number, and the day unfavorable temperature occurs, and therefore no schedule is printed for that week. Under this condition, the firm shuts down for the week, unless there is a carryover of raw products from the previous week. If available, the firm could import raw product from another area; however, this option was not provided in this study.

Table 15 shows the type of results obtained for each week using week two of the first iteration as an example. The average daily temperature over the fruit set period is equal to 65.96, and the random yield generated is 8.4 tons per acre giving a total raw product (weekly arrival) of 3,361 tons divided into 1,109 tons for whole and 2,252 tons for processed products. This amount could be processed in one day if the processing lines work at full capacity operating three shifts for whole and three shifts for processed or in two days operating two shifts each. Since the plant is assumed to work for a minimum of five days per week, the processing lines are operated for five days working one shift whole and one shift processed. Given the small amount of raw product to be processed in this week, all the production option combinations are feasible, and the least cost combintation is number one with the lowest cost of $82,083 for labor and clean-up. Lines used are 1, 2, 3, 4, 5, 8, 9, and 10 as shown in Table 15 along with the corresponding can size used, raw product equivalent processed by each line, and the production of final products in cases. The costs of each input item used in the processing operation are also illustrated in the table with total processing costs (TOTAL) of $897,315.56 for the week. The lower section of the table shows the fruit set period average daily temperature (°F), the number of days required by the plant to set fruits (Fruit Set Period), the day of the season when it begins relative to March 1st (TIME), acres planted, planting date, and yield obtained.

To illustrate the difference in the results obtained from one week to another, Table 16 presents the processing schedule for week seven of the first iteration. The amount of raw product processed this week is 8,797 tons, an increase of 5,436 tons from week one as a result of higher yields obtained at more favorable temperatures during the fruit set period. Only production combinations 10 through 15 are feasible for this week with the processing lines working at least two shifts per day for both whole and processed products. The lowest cost combintation selected is number ten, and all processing costs have increased as more processing lines are used to process the raw products.

The weekly schedules for the season are printed out in a summary table at the end of each iteration as shown in Table 17. The table presents the items included for each week's schedule as explained above plus the total of these items for the whole season.

The variability in the processing costs from one week to another is a result of the random temperatures and their effects on yields. The weekly average processing costs and average tomato yields obtained from 100 replications of the processing season as well as the coefficients of variation are presented in Table 18. The coefficient of variation (C.V.) of a variable, estimated as the standard deviation divided by the mean and multiplied by 100 to express it as a percentage, can be used to measure the relative variability of the variable's distribution. It also can be used to compare the relative variabilities of different distributions since it is unitless. Yields and processing costs obtained early and late in the season are highly variable as reflected by their coefficients of variation. This suggests that processing operations during these times of the season can be highly risky. The risk of yield reduction and/or plant damage caused by adverse temperatures early and late in the season is carried over to the processing facilities and results in highly variable processing costs.

Tomato Yields

Tomato yields are generated from triangular probability distributions conditional on the average temperature during the fruit set stage of tomato plant growth. When the temperatures are low (65° to 69°F) during this stage, most of the fruits are not expected to set, and hence the

Table 15. Processing Operations Schedule and Costs for Week 2 of Iteration One.

```
WEEK * 2    ITRTN * 1
TABLE: 2
DAYS WORKED: 5

WEEKLY ARRIVAL: 3361        DAILY WHOLE: 222      DAILY PROCESSED 450

            COST            *SHIFTS WHOLE        *SHIFTS PROCESSED
  1         82083                1.0                    1.00
  2         96319                1.0                    1.50
  3        108399                1.0                    2.00
  4        122554                1.0                    2.50
  5        125248                1.0                    3.00
  6        114874                1.5                    1.50
  7        126955                1.5                    2.00
  8        141109                1.5                    2.50
  9        143804                1.5                    3.00
 10        144439                2.0                    2.00
 11        158593                2.0                    2.50
 12        161291                2.0                    3.00
 13        177801                2.5                    2.50
 14        180503                2.5                    3.00
 15        197228                3.0                    3.00

COST ALTERNATIVE SELECTED: 1
NUMBER OF EMPLOYEES PER SHIFT: 215        0          0

LINE    CAN SIZEa          CANS            XIJT              QIJT
  1        1              220635          167.13            9193.16
  2        1              283674          214.88           11819.77
  3        1              346713          262.64           14446.38
  4        3               31519          154.81            5253.23
  5        3               63038          309.63           10506.45
  8        3               70529          762.19           11754.97
  9        4              577673          618.95           12034.86
 10        5              335856          870.65           13994.03

LABOR               67868.00
CLEAN UP            14215.00
WATER                5247.56
GAS                 44249.77
ELECTRICITY          4740.12
CARTON COSTS        11982.16
CAN COSTS          257051.06
LYE                  3216.36
SALT                 4147.95
TOMATOES           484597.62
TOTAL              897315.56

AVG DAILY TEMP: 65.96     FRUIT SET PERIOD: 11              TIME * 74

ACRES: 400.00          PLANTING DATE: 26       YIELD: 8.4022
```

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[a] Can Size 1 = 303, 2 = $2\frac{1}{2}$, 3 = 10, 4 = 6 oz, and 5 = 12 oz.

Table 16. Processing Operations Schedule and Costs for Week 7 of Iteration One.

```
WEEK * 7     ITRTN * 1
TABLE: 2
DAYS WORKED: 5

WEEKLY ARRIVAL: 8797      DAILY WHOLE: 581      DAILY PROCESSED 1179

        COST              *SHIFTS WHOLE         *SHIFTS PROCESSED
10      166305                 2.0                    2.00
11      177839                 2.0                    2.50
12      171414                 2.0                    3.00
13      195135                 2.5                    2.50
14      188422                 2.5                    3.00
15      208697                 3.0                    3.00

COST ALTERNATIVE SELECTED: 10
NUMBER OF EMPLOYEES PER SHIFT: 235        235         0

LINE     CAN SIZEa          CANS          XIJT            QIJT
 1          1              398743        302.05         16614.33
 2          1              512670        388.35         21361.27
 3          1              626597        474.65         26108.22
 4          3               56963        279.79          9493.89
 5          3              113926        559.57         18987.78
 6          2              159497        213.24          6645.73
 7          2              512670        685.43         21361.26
 8          3              126880       1371.16         21146.77
 9          4             1039212       1113.46         21650.27
10          5              604193       1566.26         25174.74
11          4              725032        776.84         15104.85
12          2              362516       1066.40         15104.85

LABOR            142580.00
CLEAN UP          23725.00
WATER             13735.65
GAS              115655.94
ELECTRICITY       12407.40
CARTON COSTS      35194.19
CAN COSTS        706219.87
LYE                8418.91
SALT              11058.86
TOMATOES         576567.81
TOTAL           1645563.00

AVG DAILY TEMP: 75.14      FRUIT SET PERIOD: 10            TIME * 107

ACRES: 400.00        PLANTING DATE: 58       YIELD: 21.9930
```

---

[a] Can Size 1 = 303, 2 = $2\frac{1}{2}$, 3 = 10, 4 = 6 oz, and 5 = 12 oz.

Table 17. Annual Production Schedules and Costs for Weeks 1-20 of Iteration 1.

ANNUAL AGGREGATE PRODUCTION PLAN FOR WEEK 1-12

WEEKS	1	2	3	4	5	6	7	8	9	10	11	12
DAYS WORKED	0	5	10	15	20	25	30	35	40	45	50	55
SHIFTS (WHOLE)	0	1	1	1	1	2	2	1	1	1	1	1
SHIFTS (PROCESS)	0	1	1	1	1	2	2	1	1	1	1	1
EMPLOYEES/SHIFT	0	225	235	233	235	233	235	235	235	235	227	235
RAW PRODUCT	0	3360	4605	4443	7329	7956	8797	7591	6928	5133	5296	7025
PRODUCTION (CASES)												
LINE 1	0	9193	8697	8391	13841	15026	16614	14337	13084	9695	14487	13267
LINE 2	0	11819	11182	10789	17796	19319	21361	18434	16823	12466	18626	17058
LINE 3	0	14446	13666	13186	21751	23612	26108	22530	20561	15236	22765	20848
LINE 4	0	5253	4969	4795	7909	8586	9493	8192	7476	5540	8278	7581
LINE 5	0	10506	9939	9590	15818	17173	18987	16385	14953	11080	16556	15162
LINE 6	0	0	3478	3356	5536	6010	6645	5735	5233	3878	0	5306
LINE 7	0	0	11182	10789	17796	19319	21361	18434	16823	12466	0	17058
LINE 8	0	11754	11069	9514	17617	23350	21146	14249	16654	9636	15543	16886
LINE 9	0	12034	11333	11689	18037	23906	21650	17506	17050	11838	15913	17288
LINE 10	0	13994	13178	13592	20973	27798	25174	20356	19826	13765	18504	20103
LINE 11	0	0	7906	8155	12584	16678	15104	12213	11895	8259	11102	12062
LINE 12	0	0	7906	0	12584	0	15104	5089	11895	3441	0	12062
AVG DAILY WHOLE	0	221	303	293	483	525	580	501	457	338	349	463
AVG DAILY PROC.	0	450	617	595	982	1066	1178	1017	928	687	709	941
COSTS (DOLLARS)												
LABOR	0	67868	70820	70159	106699	141251	142580	106699	106699	70820	103246	106699
CLEAN UP	0	14215	23725	22225	23725	22225	23725	23725	23725	23725	22225	23725
WATER	0	5247	7190	6937	11443	12422	13735	11853	10817	8015	8269	10968
GAS	0	44249	60542	54000	96354	101088	115655	92264	91085	62393	67290	92357
ELECTRICITY	0	4740	6494	6266	10336	11221	12407	10707	9771	7240	7469	9907
CARTONS	0	11982	18423	15756	29320	29825	35194	27404	27717	18531	19572	28104
CANS	0	257051	369686	328910	588361	638465	706219	551977	556185	373272	418763	563955
LYE	0	3216	4407	4252	7013	7614	8418	7265	6630	4913	5068	6722
SALT	0	4147	5789	5585	9213	10001	11058	9543	8709	6453	6536	144457
TOMATOES	0	484597	633816	291212	480346	521463	576567	497560	454077	336473	347118	460421
TOTAL	0	897315	1200894	805307	1362814	1495578	1645563	1339000	1295417	911840	1005559	1311693
ACRES NEEDED	400	400	400	400	400	400	400	400	400	400	400	400
PLANTING DAY	18	25	32	40	46	53	59	66	73	80	87	93

Table 17. (continued)

ANNUAL AGGREGATE PRODUCTION PLAN FOR WEEK 13-20

WEEKS	13	14	15	16	17	18	19	20	TOTAL
DAYS WORKED	60	65	70	75	80	85	90	90	90
SHIFTS (WHOLE)	1	1	1	1	1	1	2	1	NA
SHIFTS (PROCESS)	1	1	1	1	1	1	2	1	NA
EMPLOYEES/SHIFT	235	235	235	230	230	233	235	0	NA
RAW PRODUCT	7164	6287	7136	5735	5771	5159	9494	0	400
PRODUCTION (CASES)									
LINE 1	13531	11874	13478	14179	14269	9743	17931	0	231645
LINE 2	17397	15267	17329	18230	18346	12527	23054	0	297829
LINE 3	21263	18660	21181	22282	22423	15311	28177	0	364014
LINE 4	7732	6785	7702	8102	8153	5567	10246	0	132368
LINE 5	15464	13571	15404	16205	16307	11135	20492	0	264737
LINE 6	5412	4749	5391	5671	5707	3897	7172	0	83186
LINE 7	17397	15267	17329	0	0	12527	23054	0	230806
LINE 8	13447	15114	13395	16831	16938	15141	22823	0	281116
LINE 9	16521	15474	16457	17232	17341	15501	23366	0	300145
LINE 10	19211	17993	19136	20037	20164	18025	27170	0	349006
LINE 11	11526	10795	11482	12022	12098	10815	16302	0	201007
LINE 12	4802	10795	4784	0	0	0	16302	0	104769
AVG DAILY WHOLE	472	414	471	378	380	340	626	0	NA
AVG DAILY PROC.	960	842	956	768	773	691	1272	0	NA
COSTS (DOLLARS)									
LABOR	106699	106699	106699	104475	104475	84438	142580	0	1849610
CLEAN UP	23725	23725	23725	22225	22225	22225	23725	0	408540
WATER	11186	9817	11143	8954	9011	8055	14824	0	179895
GAS	87076	82662	86738	72868	73329	65548	124823	0	1470328
ELECTRICITY	10105	8867	10065	8088	8140	7276	13390	0	162499
CARTONS	25863	25154	25762	21289	21424	19339	37983	0	438649
CANS	520936	504755	518915	455572	458458	413997	762200	0	8987678
LYE	6856	6017	6830	5488	5523	4937	9086	0	110262
SALT	9006	7904	8971	7119	7164	6485	11935	0	0
TOMATOES	469579	412089	467758	375890	378271	338130	622271	0	8147639
TOTAL	1271034	1187691	1266610	1081972	1088022	970432	1762822	0	21899536
ACRES NEEDED	400	400	400	400	400	400	400	400	8000
PLANTING DAY	100	107	113	120	126	133	140	146	NA

Table 18. Average Weekly Tomato Yields and Processing Costs Per Ton of Processed Raw Products and Their Coefficients of Variation for the Base Model and the Two Alternative Scenarios.[a]

Week No.	Tomato		400 Acre Scenario		200 Acre Scenario		100 Acre Scenario	
	Yields	Coefficient of Variation	Processing Costs	Coefficient of Variation	Processing Costs	Coefficient of Variation	Processing Costs	Coefficient of Variation
	Tons/Acre	%	$/ton	%	$/ton	%	$/ton	%
1	3.75	140.9	274.33	0.8	292.36	1.1	316.05	2.3
2	9.30	59.1	267.73	0.9	276.47	4.3	298.86	5.2
3	13.30	41.4	259.94	1.0	260.89	3.5	279.30	5.3
4	18.13	27.3	185.50	1.8	190.83	5.5	201.47	7.4
5	19.63	18.6	183.64	2.3	191.56	5.6	198.57	6.3
6	20.34	13.8	183.72	2.2	182.90	3.8	187.98	4.5
7	20.69	13.2	183.20	2.3	183.95	3.9	189.44	4.3
8	20.72	14.6	182.63	2.3	189.75	5.5	195.62	5.8
9	18.70	17.6	183.67	2.4	186.86	5.0	193.75	5.6
10	16.28	17.3	184.74	2.3	185.15	4.5	194.94	4.9
11	16.38	15.4	185.66	1.9	183.29	3.2	192.33	3.5
12	14.96	12.5	185.06	2.0	186.15	4.8	197.99	5.4
13	15.02	15.1	186.47	2.0	188.25	5.2	199.89	5.5
14	14.69	15.8	185.12	2.2	188.65	5.1	201.22	6.0
15	15.63	13.6	186.04	2.0	186.96	5.0	197.25	5.6
16	15.78	12.6	185.19	2.2	186.28	5.0	196.22	4.9
17	15.48	19.5	186.05	2.0	186.50	4.9	196.47	4.9
18	16.38	30.6	185.18	2.2	189.98	5.6	198.77	5.5
19	15.18	55.8	183.78	2.3	185.43	4.6	192.08	4.7
20	5.76	162.9	184.03	2.3	186.47	4.9	191.74	5.4

[a] The weeks within the iterations where no yields were obtained are not included in the computations of processing cost figures.

expected per acre tomato yield will be low. As temperatures rise, yields will increase up to a certain level and then decline as temperatures rise above the maximum threshold of 80°F beyond which fruit set is reduced. If frosts occur, the tomato plant will be damaged, and yields will be zero or too low to be considered. The coefficient of variation for the first and last few weeks are very high, indicating that the distribution of tomato yields during these weeks varies widely as a result of the hostile temperatures (Table 18). Figure 5 illustrates the distribution of per acre average tomato yields obtained from 100 iterations of each week of the processing season.

Expected Profits

The firm's performance can be measured by several interrelated factors which include profitability, capital position, cash flow adequacy, size, productivity, and efficiency. In this application, only profitability is considered. Several methods have been developed to measure the profitability of a business firm. The two most common measures are net income (profits) and returns to equity capital. Net income, with which this analysis is concerned, is defined as the difference between the firm's total revenues and total costs excluding taxes and insurance, or

$$\pi = TR - TC$$

where π = profits, TR = total revenue, TC = total cost.

Total revenue of the firm was calculated as the sum of the number of cases produced by each processing line during the season multiplied by their respective unit price for the different types of final products. Fixed costs of the processing facility were amortized to estimate the annual fixed costs and were added to the variable processing cost to determine the total processing costs incurred during the season. Therefore, profits or net income of the firm can be written as

$$\pi = \sum_{i} Q_i P_i - (\underset{j}{S} SN_{ij}C_{ij} + FC)$$

where Q_i is the total amount of final product produced by line i, Pi is the price per case, FC is the fixed costs, N_{ij} is the number of shifts worked by line i in week j, and C_{ij} is the variable costs per shift of operating line i in week j.

To determine the probabilities of various levels of profits based on the assumptions used to build the model, the results obtained were plotted as a cumulative probability (Figure 6). The average expected pre-tax profits obtained from 100 replications is about $2.6 million with a coefficient of variation of 25 percent. The results suggest that if the total costs estimated reflect the true costs and if prices for the final products remain unchanged, the firm can make pre-tax profits given the

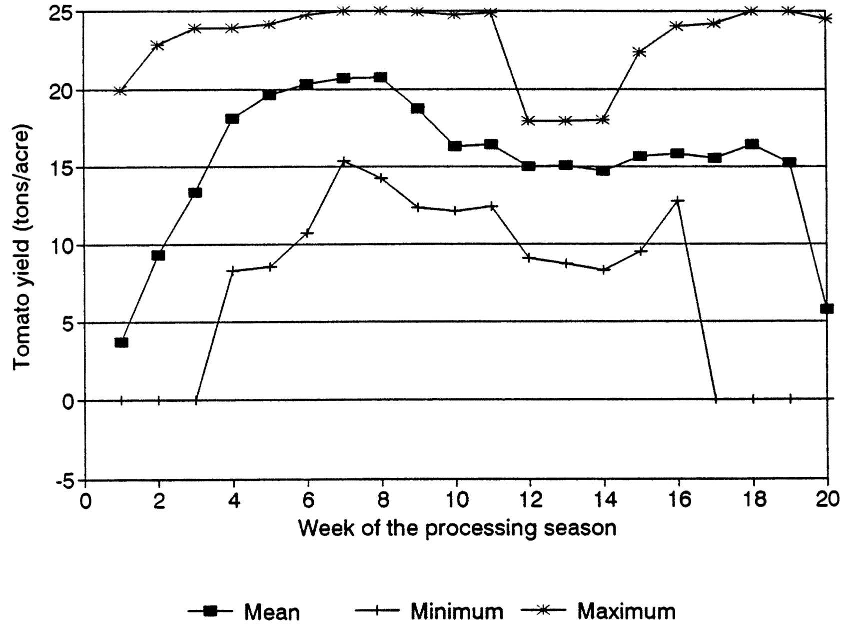

Figure 5. Weekly Mean, Minimum, and Maximum Tomato Yields for 100 Iterations.

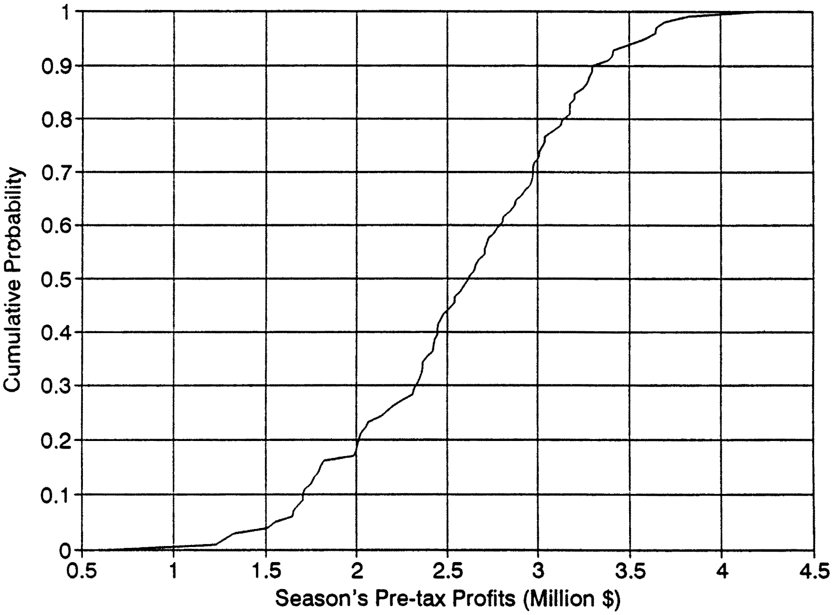

Figure 6. The Cumulative Probability Distribution of Expected Pre-tax Profits from 100 Iterations for the 400 Acre Plan.

unexpected changes in temperatures. Whether $2.6 million is sufficient to cover taxes, insurance, and generate an adequate return on investment must be decided by potential investors. The $2.6 million provides a 4.66 percent return on investment.

Alternative Plans

The model discussed so far in this study is based on operating specifications for an existing California tomato processing firm with a given number of processing lines at a given rated capacity and a fixed combination of final product. Operating at full capacity, the firm can process more than 129.4 tons of raw product per hour at 70 percent efficiency.

With an initial specification of 400 acres per week (8,000 acres for the season) for raw tomato production, the results obtained for this application show that the processing lines are operating at less-than-full capacity, and some of them were not used when generated yields were low. Specification of a smaller processing firm may be more realistic since the processing tomato crop is new to the area, and inexperienced farmers may not be willing to grow the 8,000 acres of a new crop, especially since it is associated with a relatively high yield risk. The outcome of the model suggested the need to consider alternative plans. Two alternative plans are examined in which fewer processing lines and fewer acres are planted. In the first alternative plan, the processing lines are reduced to four lines (lines 5, 7, 8, and 12 from Table 2), and the number of acres are reduced to 200 per week (4,000 acres for the season). The second alternative plan considers only 100 acres per week (2,000 acres for the season) and four processing lines. The processing lines were chosen to allow the firm to concentrate on institutional can sizes.

Results and Comparison of the Two Alternative Plans

The input data and assumptions used to run the model under these two plans are consistent with the base model except for the number of processing lines, the estimated fixed costs, and the number of acres planted for tomatoes. Annual fixed costs for the two alternative plans are estimated at $2,473,672 each which includes all the items specified for the base model but at levels consistent with the four processing lines chosen for these two plans.

Results obtained from the model under these two plans are analyzed in terms of the weekly per ton processing costs and the expected profits generated under the seasonal variations in temperatures. The average per ton processing costs for each week of the simulated season for both plans and their coefficients of variation are presented in Table 18 along

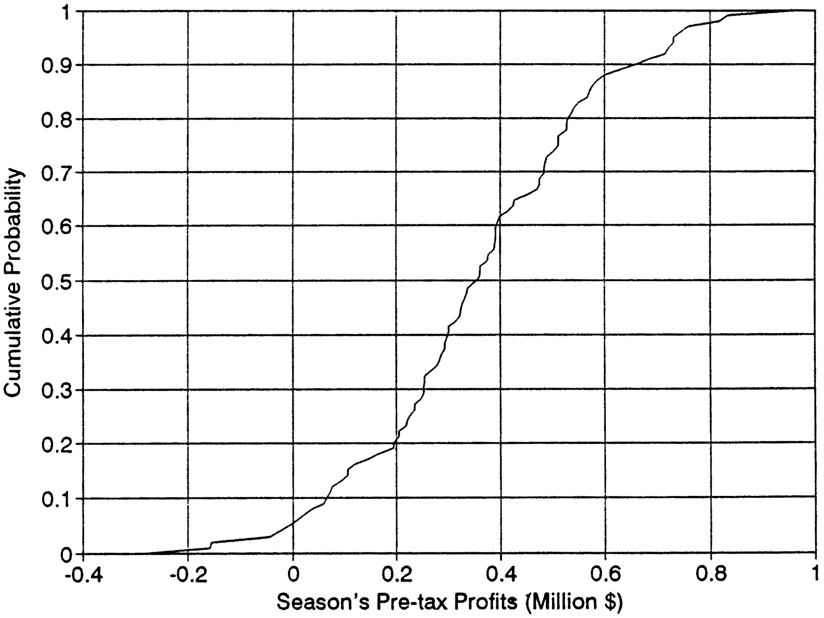

Figure 7. The Cumulative Probability Distribution of Expected Pre-tax Profits from 100 Iterations for the 200 Acre Plan.

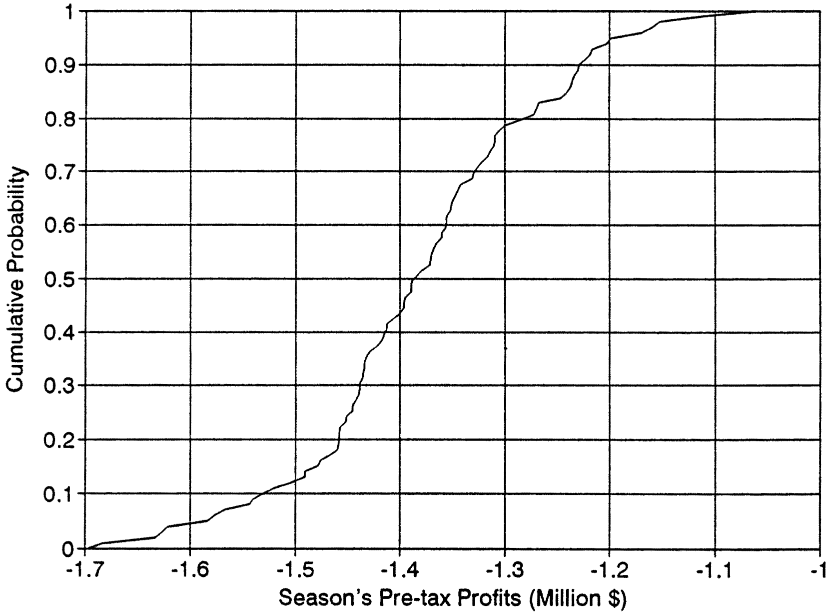

Figure 8. The Cumulative Probability Distribution of Expected Pre-tax Profits from 100 Iterations for the 100 Acre Plan.

with the per ton processing costs and the coefficients of variation obtained from the base model. Given the amount of raw products obtained from 200 acres each week, average processing costs for each week are generally lower than those when 100 acres are used to obtain the raw products with the same number of processing lines. The baseline model (400 acres per week) resulted in lower average processing costs for all but two weeks.

The expected profits generated for each simulated season are presented as cumulative probability distributions in Figures 7 and 8 for the first and second alternative plans. The figures indicate that under the 200 acre plan the probability of making at least some pre-tax profits is 0.95, while under the 100 acre plan the probability of losing at least one million dollars is 1. The results suggest that to establish the investment, the number of acres devoted to raw product production should be greater than 100 acres under the proposed number of processing lines.

Summary and Conclusions

With the declining returns from traditional crops in the southeastern part of Oklahoma, farmers are eager to consider alternatives to improve their incomes. Vegetables have been considered as potential alternative crops, and the growing conditions in the area are favorable. With the increased interest in vegetable production, vegetable processing is considered as a potential market and a chance for improving the agricultural sector in the area. Vegetable processing requires a uniform flow of consistent quality raw products to a processing plant. This flow is hampered by unpredictable weather.

A vegetable processing industry in the area would be faced with uncertainty of raw product availability due to unpredictable weather. Also, firms may face uncertainty about the acreage required to supply a firm with raw product as most vegetable crops in the region are associated with high production risks which inhibit new farmers from producing the crops.

Tomatoes for processing have been considered in this study to analyze the effect of uncertain temperatures on the costs of processing tomatoes in the study area and to estimate the possibility that an established processing firm would make profits given the stochastic temperatures and yields and the available raw product acreages.

The methodology chosen to analyze the effect of stochastic tomato yields caused by the unpredictable temperature variation on the costs of tomato processing operation was simulation analysis. A stochastic simulation model was developed based on a simulation model available from California. The basic structure of the model is depicted by the flow chart of Figure 2.

The model was designed to find the least cost combination in terms of the rates and processing time of various levels of output, given the amount of raw products available during each week of the processing season. To estimate the weekly flow of raw products to the firm, tomato yields were generated stochastically from triangular probability distributions conditional on the average daily stochastic temperatures during the fruit set stage of the tomato plant growth. Stochastic temperatures were drawn randomly from empirical probability distributions using 33 years of historical data. The planning schedule for the season was simulated 100 times to determine the probabilities and the expected values of the yield, the processing costs, and the profits.

Results obtained from 100 iterations of the 20-week processing season were used to validate the model. Stochastic temperatures generated were compared statistically and graphically with historical data, and were found to be satisfactory. The means and standard deviations of the daily temperatures were tested using the t-test and F-test, and the correlation coefficients for the estimated temperatures were estimated and compared to those of the actual data. Stochastic yields generated from conditional subjective triangular probability distributions were plotted as cumulative distributions for particular temperature ranges and harvesting dates. Processing schedules produced by the model depicted the number of days worked, the number of processing lines and their levels of production of final products, processing operation costs, per acre yields, planting dates, and the fruit set periods and times for each week of the 20-week processing season.

The results were analyzed in terms of the variability of processing costs caused by the stochastic temperatures through their impact on yields. The coefficient of variation was used to measure this variability. It indicated that early and late in the season yields, and hence processing costs, are highly variable. The average expected profit for the season for the processing plant was estimated at about $2.6 million with a coefficient of variation of 25 for the 400 acre baseline plan. This estimate was based on the assumptions that no variable costs are incurred when no raw products were delivered due to adverse temperatures and that labor was available on a call basis. If these assumptions do not hold, expected profits could be more variable as temperatures vary from one season to another. The expected profits obtained from 100 iterations of the season were plotted as a cumulative probability distribution in Figure 6.

Because the model was based on specifications for an existing California processing firm, acres devoted to raw tomato production were set initially at 400 per week (8,000 acres for the season) to determine if the specified firm could be adopted to the study area. The results obtained suggested the need for alternative plans. Therefore, the model was run under two alternative plans in which the size of the firm and the number of acres were reduced. The first alternative plan consisted of 4 processing lines and 200 acres per week (4,000 acres for the season), and the second plan consisted of the same 4 processing lines but with only 100 acres per week (2,000 acres for the season). The results indicated that the 200 acre plan had lower costs per ton of processed raw products and was more profitable when compared with the 100 acre plan which always shows a pre-tax loss of at least one million dollars. The 200 acre plan had a probability of 0.95 of making at least some pre-tax profits. Costs per ton were higher and profits lower than when the firm contained 12 processing lines and 400 acres per week.

Limitations and Suggestions for Further Research

The main limitation for this study was the availability of data regarding tomato yields for a specific cultivar, heat units required by the plant for various developmental growth stages, and harvesting and/or planting dates. The application of this model was based on assumptions considered appropriate for Southeastern Oklahoma which may not be applicable for other areas. The model can be modified further to accommodate more environmental factors affecting processing firm operations. Capital budgeting techniques also could be incorporated.

The model can be made more diverse by including different or mixed commodities for processing. Input data, including raw tomato prices and final product prices, could be generated stochastically from specified probability distributions to reflect real world behavior.

Another limitation imposed on the study was the use of the corrected mean method for heat unit calculations. It was selected because data required for alternative methods are not available. Experimentation with the model using the sine function method was carried out assuming the same heat unit requirements used for the corrected mean method. These results gave a five-day range in the fruit set period when plantings start early and late in the season. The sine function method has the capability of estimating the heat units considering the negative effect of too high temperatures which leads to plant development delay. Collection of tomato yield data and heat units from experimental plots in Oklahoma would allow application of the sine function method.

Finally, this study only considered a simple measure of profitability. Before undertaking the establishment of a processing firm, investors should consider cash flow and capital budgeting analysis.

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APPENDIX A

LABOR TABLES

Table 19. Labor Requirements for Sequential Use of Tomato Processing Lines.

Stage Employees	Labor Class	Labor Option A No. of Employees	Labor Option M No. of Employees
I. Receiving & general preparation			
Supervisor	1	1	1
Weigh master	2	1	1
Janitor/cleanup	3	2	2
Crew leader	4	1	1
Bulk dumping worker	5	2	1
Lift driver	6	1	1
Flume control operator	7	2	1
Trash sorter	8	28	8
II. Preparation--whole tomatoes			
Supervisor	9	1	0
Sorter	10	38	0
Crew leader	11	1	0
Lye peel operator	12	1	0
Janitor/cleanup	13	2	0
Ingredient supplier	14	1	0
Merry-go-round	15	1	0
III. Preparation--products			
Supervisor	16	0	2
Pan operator	17	0	2
Cook's helper	18	0	1
Hot break worker	19	0	1
Finisher	20	0	1
Sauce blender	21	0	1
Janitor	22	0	1
Sorter	23	0	4
IV. Filling and processing--products			
Products supervisor	24	0	1
Depalletizer	25	0	3
Can chaser	26	0	1
Seamer operator	27	0	1
Sterilizer	28	0	1
Janitor	29	0	1
V. Filling and processing--whole			
Filler	30	15	0
Crew leader	31	1	0
Seamer operator	32	1	0
Depalletizer	33	4	0
Can chaser	34	2	0
Empty can lift transporter	35	1	0
Janitor	36	2	0
VI. General processing			
Cook room supervisor	37	1	1
Seamer mechanic	38	1	1
Seam checker	39	2	1
Janitor	40	1	1

Table 19. (continued)

	Die setter	41	1	1
	Greaser	42	1	1
	Lid trucker	43	1	1
	Red light hopper	44	1	0
	Empty can shrouds	45	1	1
	Cooker mechanic	46	1	0
	Switchman	47	1	1
	Empty can supplier	48	1	1
VII.	General service			
	Supervisor	49	0	0
	Supervisor (cleanup)	50	1	1
	Boiler operator	51	1	1
	Electrician	52	1	1
	Cooking tower worker	53	1	1
	Line mechanic	54	4	1
	Sanitation worker	55	1	1
	Janitor	56	2	2
	Personnel clerk	57	1	1
	Time keeper	58	1	1
	Nurse	59	1	1
	Quality control supervisor	60	1	1
	Lab worker	61	8	3
	Oiler/greaser	62	1	1
	Screening plant worker	63	1	1
	Payroll clerk	64	1	1
VIII.	New can stacking			
	Supervisor	65	1	1
	Stock checker	66	1	1
	Palletizer	67	7	4
	Hand fork truck operator	68	10	0
	Lift truck operator	69	2	1
	Transport train operator	70	1	1
	Mechanic	71	2	2
	Mechanic's helper	72	1	0
	Cleanup worker	73	1	1
	Pack accounting clerk	74	1	0
	Stretch wrap worker	75	2	1
IX.	Cooling floor			
	Stock checker	76	1	1
	Lift truck operator	77	2	1
X.	Pack receiving			
	Stock checker	78	1	1
	Lift truck operator	79	4	2

Given LO(A), then LO(B) = LO(A) + 1 employee #8 + 1 #10 + 1 #32. Given LO(A), then LO(C) = LO(A) + 2 employee #8 + 2 #10 + 2 #32. Given LO(A), then LO(D) = LO(A) + 3 employee #8 + 4 #10 + 3 #32. Given LO(A), then LO(E) = LO(A) + 4 employee #8 + 6 #10 + 4 #32. Given LO(A), then LO(F) = LO(A) + 5 employee #8 + 7 #10 + 5 #32. Given LO(A), then LO(G) = LO(A) + 6 employee #8 + 8 #10 + 6 #32.

Table 19. (continued)

The following processed products labor options are added to the option selected from the set LO(A) through LO(G). LO(H) adds 3 employee #8; 2 #16; 2 #17; 1 #18; 1 #19; 1 #20; 1 #21; 1 #22; 4 #23; 1 #24; 3 #25; 1 #26; 1 #27; 1 #28; and 1 #29. Given LO(H), then LO(I) = LO(H) + 1 employee #27. Given LO(H), then LO(J) = LO(H) + 2 employee #27. Given LO(H), then LO(K) = LO(H) + 3 employee #27 + 1 #68. Given LO(H), then LO(L) = LO(H) + 4 employee #27 + 2 #68.

Given LO(M), then LO(N) = LO(M) + 1 employee #27. Given LO(M), then LO(O) = LO(M) + 2 employee #27. Given LO(M), then LO(P) = LO(M) + 3 employee #27. Given LO(M), then LO(Q) = LO(M) + 4 employee #27.

Source: Logan (1984).

Table 20. Hourly Wages for Different Classes in Each Stage of the Processing Operations.

Stage & work classification [a] for the processing plant operations	Work classification [b] substitute in terms of occupation and/or wage (McAlester area)	$/Hour
Stage I. Receiving & General Preparation		
1. Supervisor	Warehouse supervisor	$10.41
2. Weigh master	Shipping & receiving clerk	4.24
3. Janitor/cleanup	Janitor, cleaners	4.45
4. Crew leader	General maintenance	6.04
5. Bulk dumping worker	Trucker: hands	4.75
6. Lift driver	Trucker, local haul	6.19
7. Flume control operator	General maintenance	6.04
8. Trash sorter	Cleaner	4.45
Stage II. Preparation--whole tomatoes		
9. Supervisor	Warehouse supervisor	10.41
10. Sorter	Cleaner	4.45
11. Crew leader	General maintenance	6.04
12. Lye peel operator	General repair, maintenance	6.04
13. Janitor/cleanup	Janitor/cleaner	4.45
14. Ingredient supplies	Stock handler	5.20
15. Merry-go-round	Tellers, all around	3.88
Stage III. Preparation products		
16. Supervisor	Warehouse supervisor	10.41
17. Pan operator	Warehouse supervisor	10.41
18. Cook's helper	General maintenance repairs	6.04
19. Hot break worker	General maintenance	6.04
20. Finisher	Stock handler	5.20
21. Sauce blender	Cleaner	4.45
22. Janitor	Janitor	4.45
23. Sorter	Cleaner	4.45
Stage IV. Filling and processing products		
24. Products supervisor	Warehouse supervisor	10.41
25. Depalletizer	Stock handler	5.20
26. Can chaser	Cleaners	4.45
27. Seamer operator	Maintenance, repairs	6.04
28. Sterilizer	Stock handler	5.20
29. Janitor	Janitor	4.45
Stage V. Filling and processing whole		
30. Filler	Porters, clears	4.45
31. Crew leader	General maintenance	6.04

Table 20. (continued)

32. Seamer operator	Stock handler	5.20
33. Depalletizer	Stock handler	5.20
34. Can chaser	Cleaners	4.45
35. Empty can lifter	Porter	4.45
36. Janitor	Janitor	4.45
Stage VI. General processing		
37. Cook room supervisor	Warehouse supervisor	10.41
38. Seamer mechanic	Mechanics	10.97
39. Seam checker	Stock handler	5.20
40. Janitor	Janitor	4.45
41. Die setter	Stock handler	5.20
42. Greaser	Auto maintenance	7.83
43. Lid trucker	Truckers, local haul	6.19
44. Red light hopper	Maintenance, repairs, general	6.04
45. Empty can shrouds	Cleaners	4.45
46. Cooker mechanics	Mechanics, maintenance	10.97
47. Switchman	Janitors	4.45
48. Empty can supplier	Porter	4.45
Stage VII. General services		
49. Supervisor	Warehouse supervisor	10.41
50. Supervisor (cleanup)	Maintenance, general	6.04
51. Boiler operator	Mechanics, auto maintenance	8.75
52. Electrician	Mechanics, auto maintenance	8.75
53. Cooking tower worker	Truckers hauls	5.20
54. Line mechanic	Mechanic, maintenance	10.97
55. Sanitation worker	Cleaner	4.45
56. Janitor	Janitor	4.45
57. Personnel clerk	General clerks	4.24
58. Time keeper	General clerks	4.24
59. Nurse	Secretaries office	6.50
60. Quality control supervisor	Mechanics, maintenance	8.75
61. Lab worker	Stock handler	5.20
62. Oiler/greaser	Auto maintenance	7.83
63. Screening plant worker	General repairs & maintenance	6.04
64. Payroll clerk	Payroll clerk	5.96
Stage VIII. New can stacking		
65. Supervisor	Warehouse supervisor	10.41
66. Stocker checker	Stock handler	5.20
67. Palletizer	Stock handler	5.20
68. Hand fork truck operator	Trucker, local haul	6.19
69. Lift truck operator	Truck driver	6.73
70. Transport truck operator	Trucker, local haul	6.19
71. Mechanic	Mechanic, maintenance	10.97
72. Mechanic helper	Trucker's hands	5.20

Table 20. (continued)

73. Cleanup worker	Cleaner	4.45
74. Pack accounting clerk	Shipping & receiving clerk	4.29
75. Stretch lab worker	Shipping & receiving clerk	4.29
Stage IX. Cooling floor		
76. Stock checker	Stock handler	5.20
77. Lift truck operator	Truck driver	6.73
Stage X. Pack receiving		
78. Stock checker	Stock handler	5.20
79. Lift truck operator	Truck driver	6.73

[a] Source: Logan (1984).

[b] Source: Center for Economic and Management Research (1988).

APPENDIX B

PROCESSING TOMATO PRODUCTION BUDGET

Table 21. Processing Tomato Production Budget, Direct Seeded and Machine Harvest for Southeastern Oklahoma.

Operating Inputs:	Units	Price	Quantity	Value
Vegetable seed	lbs.	35.000	1.000	35.00
Nitrogen (N)	lbs.	0.170	60.000	10.20
Phosphate (P205)	lbs.	0.150	100.000	15.00
Potash (K20)	lbs.	0.100	100.000	10.00
Lexone .75 lb AI	acre	2.000	1.000	2.00
Copper Sulfate 2 lb. AI	acre	2.500	4.000	10.00
Dithane-M45 1.6 lb. AI	acre	3.400	3.000	10.20
Difolatan 1.6 lb. AI	acre	12.000	1.000	12.00
Sevin 1 lb. AI	acre	5.000	3.000	15.00
Thiodan .75 lb. AI	acre	7.800	1.000	7.80
Ripener	gal.	95.000	0.850	80.75
Hoeing labor	hr.	4.500	15.000	67.50
Crop insurance	acre	40.000	1.000	40.00
Cover crop	acre	8.000	1.000	8.00
Annual operating capital	dol.	0.118	77.089	9.06
Labor charges	hr.	4.500	11.583	52.03
Machinery fuel, lube, repairs	acre			96.83
Irrigation fuel, lube, repairs	acre			35.64
Total Operating Cost				517.01

Fixed Costs		
Machinery		
Interest at 11.8%	dol.	116.303
Depr., taxes, insurance	dol.	148.703
Irrigation		
Interest at 11.8%	dol.	17.480
Depr., taxes, insurance	dol.	19.800
Land		
Interest at 0.0%	dol.	0.000
Taxes	dol.	0.000
Total Fixed Costs		302.27

Production:	Units	Price	Quantity	Value
Tomatoes	tons	65.540	15.000	983.10
Returns above Total Operating Costs				466.09
Returns above All costs except Overhead, Risk and Management				163.82

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