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# Evaluating Optimal Product Mix Using Dynamic Simulation: A Tomato Processing Case

**Andrew Swire-Thompson, Thomas L. Sporleder, David E. Hahn, and Winston Bash**

Technology-driven change is everywhere and value-capture from new technology is challenging for business managers. Also rival firms may use technology as part of major success strategies. This situation leads managers to be keenly interested in evaluation of alternative technologies prior to making a sunk investment in physical facilities. In contemplating new or added-capacity processing facilities, managers and investors must evaluate return on investment (ROI). Evaluation of ROI is complex because it varies by alternative technology and the resultant potential product mix alternatives associated with that technology at the time the investment capital is committed to build the processing plant.

This research examines optimal alternative product mix from a processing plant technology that is fixed at the time of commitment to building or adding capacity. Evaluating the optimal product mix is of vital concern in any start-up processing environment. In this research the optimal product mix is evaluated by using a sophisticated evaluative tool known as PowerSim. This economic simulation software is used to model a start-up tomato processing plant in Ohio. The model evaluates the effects of various output, or tomato product mix, on plant profitability measured by ROI.

Results indicate that an increase in plant profitability is expected when the tomato product mix consists of products that have a lower soluble solids concentration. The lower the soluble solids concentration of a tomato product, the less the processor will benefit from tomato varieties with high soluble solids. The processing operation achieves a ROI of 26.5 percent when the plant's product mix is 50 percent tomato paste (31° brix) and 50 percent diced tomatoes. This product mix optimizes processor net income and realizes a plant return on equity of 50.6 percent.

## Introduction

Technology-driven change is everywhere and value-capture from new technology is challenging for business managers. Also rival firms may use technology as part of major success strategies. This situation leads managers to be keenly interested in evaluation of alternative technologies prior to making a sunk investment in physical facilities. In contemplating new or added-capacity processing facilities, managers and investors must evaluate return on investment (ROI). Evaluation of ROI is complex because it varies by alternative technology and the resultant potential product mix alternatives associated with that technology at the time the investment capital is committed to build the processing plant.

The first three authors are former graduate associate in agribusiness, professor and Income Enhancement Endowed Chair, and professor, respectively, Department of Agricultural, Environmental, and Development Economics, The Ohio State University. Winston Bash is director, Food Industries Center, and professor, Department of Food Science and Technology, The Ohio State University.

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A typical tomato processing plant is a complex array of activities. Tomatoes are channelled down two processing lines to produce one of two broad tomato product outputs, paste or peeled (Starbird and Ghiassi, 1984). The manufacture for paste products involves the pulping of tomatoes, the extractions of skins and seeds from the pulp and the addition of flavoring ingredients for final product differentiation, Figure 1. Industrial tomato paste, catsup, spaghetti sauce and pizza sauce are examples of paste products (Starbird and Ghiassi, 1986).

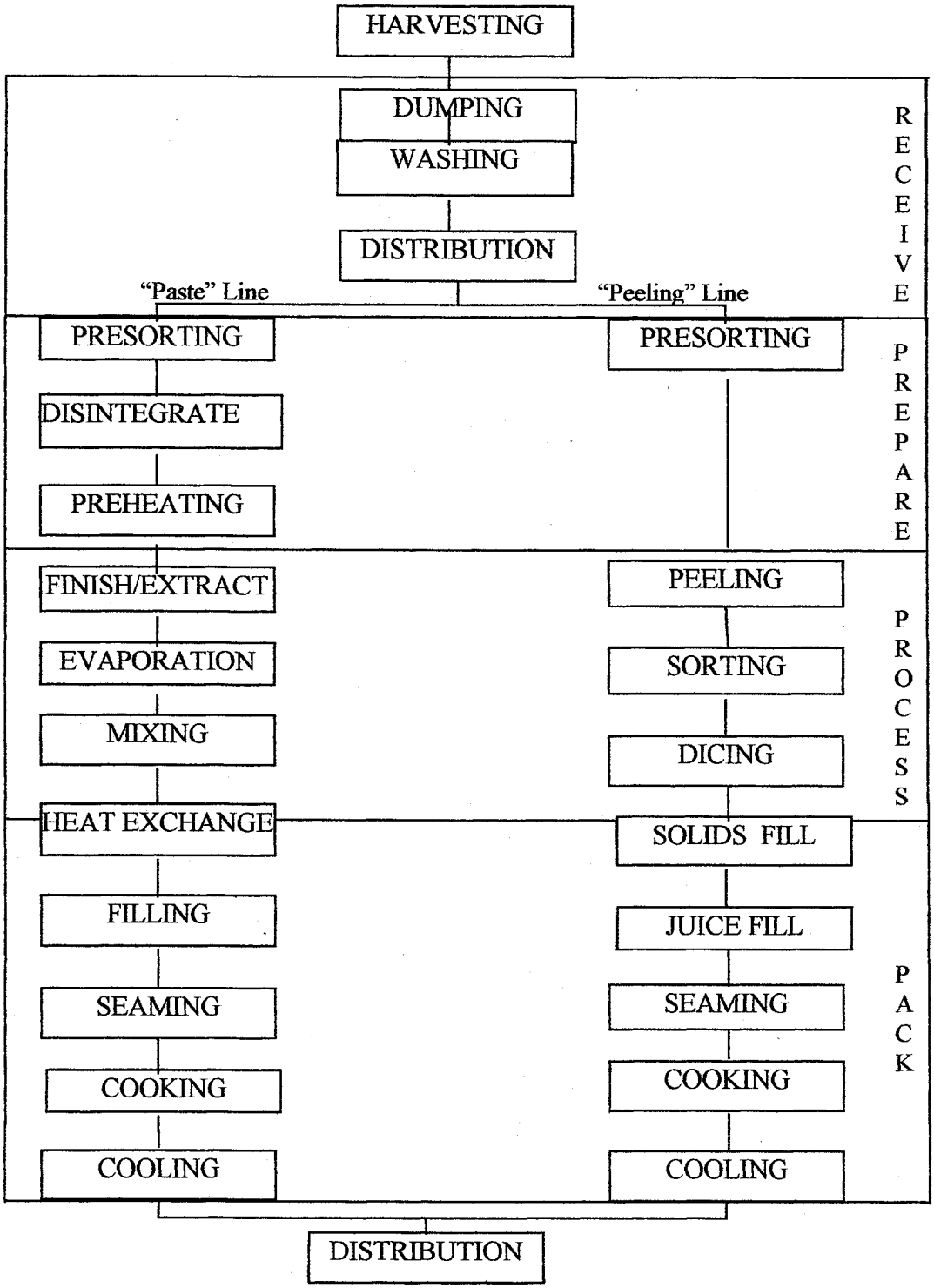


**Figure 1. Major Functions of a Tomato Processing Operation (Starbird & Ghiassi, 1986).**

Peeled tomato products are manufactured by peeling whole tomatoes, chopping the tomatoes into different sizes, adding ingredients and canning the product (Starbird & Ghiassi, 1986). Color is one of several quality factors important in the manufacture of peeled tomato products (Gould, 1992). Examples of peeled tomato products include salsa, dices and whole peeled tomatoes.

## Production of Tomatoes for Processing

Processing tomato production in the United States increased from 10.23 million metric tons in 1996 to 10.9 million metric tons in 1999 (McNeil, 2000). In 1998 the U.S. processing tomato crop was valued at $542.5 million (CTGA, 2000). California produces 95% of processing tomatoes in the United States; Ohio produces 2%, Indiana 2% and other states 1% (Plummer, 1999).

California has increasingly dominated the processing tomato market in the United States. A relatively longer growing season and therefore processing season along with production of tomatoes with relatively high soluble solids and higher processing yield per ton combine to put California in the dominant position.

Processing tomatoes are harvested and processed over approximately 105 days in California versus 50 days in Ohio. The average natural tomato soluble solids (NTSS) content in California is 5.13° brix (PTAB, 2000) versus 4.14 ° brix in Ohio (Francis, 2000). Processing tomato crop yields are approximately 35 tons per acre in California (CASS, 1999) versus approximately 30 tons per acre in Ohio (Francis, 2000).

## Methods to Evaluate Optimal Technology and Product Mix

This research is based on a dynamic economic model to simulate an Ohio tomato processing plant and to evaluate tomato product mix alternatives for the start-up plant. The primary objective is to determine the ratio of tomato paste production to diced tomato production that produces optimal ROI eater than 20%, based on conventional processing technology.

Factors influencing profitability, as measured by ROI and return on equity (ROE), include the scale of the project, as measured by total assets. Other factors are the debt-to-equity ratio and the estimated total revenues and estimated total operating costs, Figure 2. This particular research focuses on product mix (ratio of paste product to diced tomato product). Identifying major factors that influence tomato processor profitability requires focusing on the items influencing total processor revenues, total processor operating costs and total processor assets.

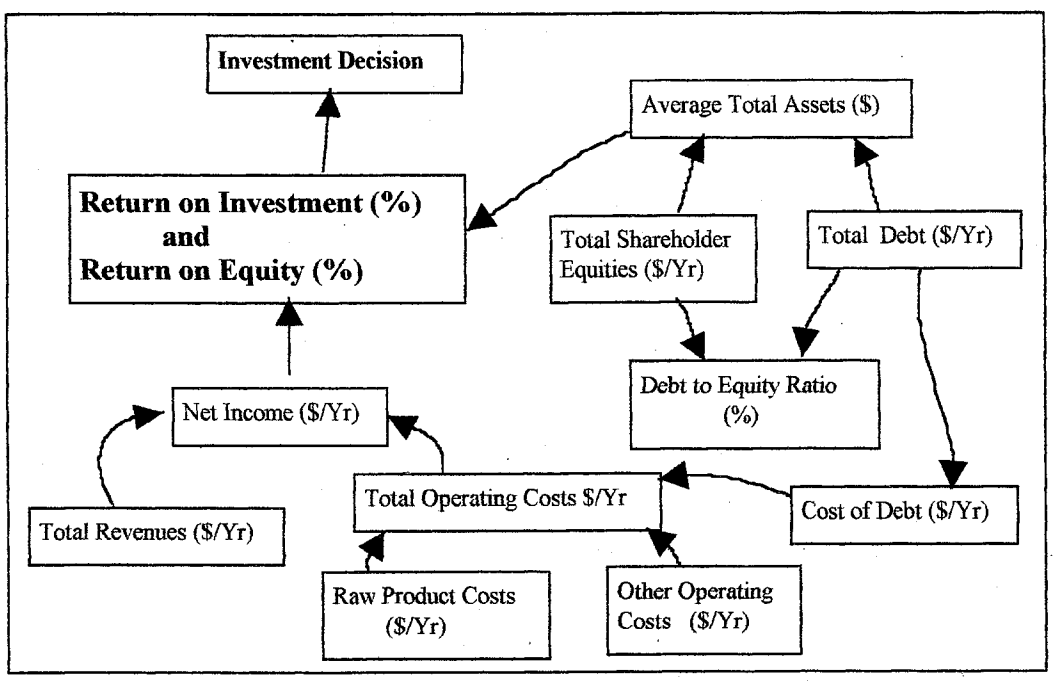


**Figure 2. Influence Diagram Representing Factors in Analyzing a Potential Investment Decision.**

Finished tomato product throughput and finished tomato product price directly influence total processor revenues, Figure 3. Throughput of the finished tomato product is dependent on market demand for the product, while the price of the finished tomato product is dependent on market forces and quality characteristics of the finished tomato product. These quality and component factors include viscosity, color, soluble solids and mold. Other factors such as age of final product, cash flow, and specific design of customer's remanufactured product also contribute to the final price of processed tomato products (CTGA, 2000).

Total tomato processor operating costs are primarily determined by production operating costs: labor, utilities, packaging, sales cost, supplies, carrying interest, overhead and repair and maintenance, depreciation, property taxes and insurance, salaries and benefits, raw tomato product costs, the agronomic characteristics of the raw tomatoes, solids recovery from processing, and raw input capacity of the processing plant. Increasing raw tomato supply requirements per unit of output increases processor raw product costs. Depending on the finished tomato product, premiums may be paid for enhanced agronomic characteristics such as raw tomato solids content, color and raw tomato quality characteristics (CTGA, 1998).

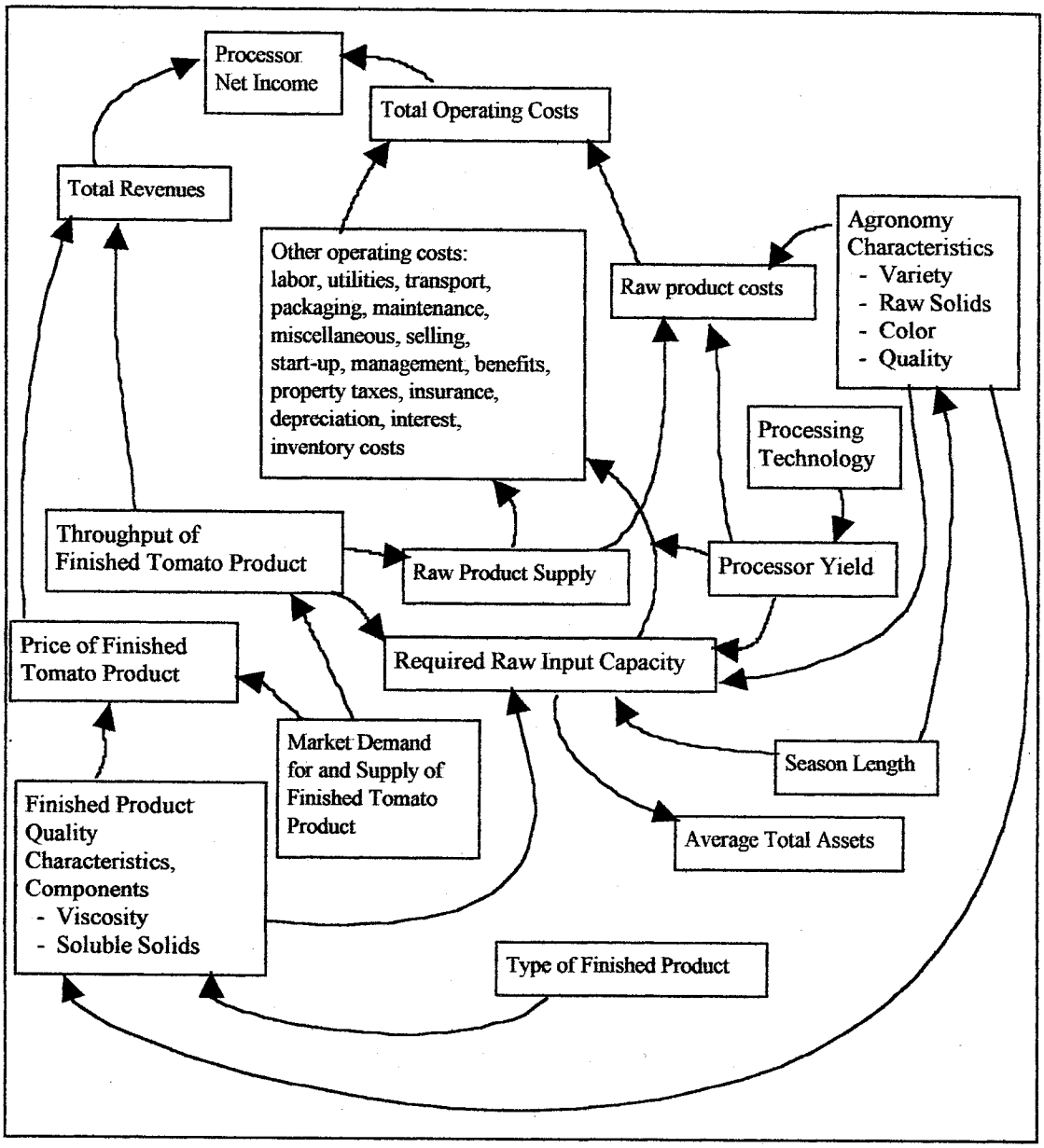


**Figure 3. Influence Diagram Illustrating Major Factors Influencing Tomato Processor Profitability.**

Agronomic characteristics of processing tomatoes vary according to growing region. For example, the average raw tomato soluble solids content of tomatoes in California is approximately 5.13° brix (PTAB, 2000), while in Ohio it is approximately 4.14° brix (Francis, 2000). A high average raw tomato soluble solids content translates into lower processor raw product supply requirements and consequent lower processor raw product costs per unit of output. Agronomic characteristics play an important role in determining the quality of finished tomato product.

Higher raw product solids recovery in the processing plant decreases processor raw tomato supply requirements and therefore reduces raw product costs. Solids recovery is influenced by the processing technology of the plant.

Also, raw input processing capacity can influence tomato processor operating costs. Increased raw input capacity allows for increased finished product throughput and hence, decreases average total operating costs per unit. Major determinants of raw input capacity include solids recovery in the plant, the soluble solids content of the raw and finished product, and the length of the processing season.

An increase in processor solids recovery will decrease required raw input capacity due to lower raw product requirements per unit of output. Higher average raw soluble solids lead to a decrease in processor raw tomato requirements and therefore raw processing capacity requirements. Processors producing finished tomato products with higher soluble solids content (i.e., 31° brix tomato paste) require a higher raw input processing capacity. This is because greater quantities of raw product (for 31° brix vs. 12° brix) are required to produce a similar amount of throughput.

## Simulation Using PowerSim

Anderson, Sweeney and Williams define simulation as follows:

> Simulation is the process of studying the behavior of a real system by using a model that replicates the behavior of the system. A simulation model is constructed by identifying the mathematical expressions and logical relationships that describe how the system operates. Generally a computer is used to perform the computations required by the simulation model.

Simulation of the processing plant activities allows analysis of the economic effects of product mix, an important consideration for investors in a potential tomato processing facility. An Ohio benchmark simulation is used as a reference point to which the product mix scenario simulations are compared.

The model is constructed using extensive data. The software used to construct the model is PowerSim Constructor 2.5 (PowerSim, 1996). A variety of PowerSim Constructor tools are used in model construction. These tools include stocks, flows, arrays, constants, auxiliaries and information connector links. The application of these tools is discussed here along with the presentation of some of the model structures that determine the product mix of the plant. The time period for the model simulation is set at the season length of the proposed geographic area for plant. An Ohio season length is set at 50 days (Senechal, 1997).[1]

## Analysis of Optimal Product Mix

Factors important to optimal product mix for a processor are:

- estimated demand for tomato products,
- processor raw product requirements,
- soluble solids content of the finished tomato products produced,
- production quantities of finished tomato products,
- NTSS of raw product, and
- price for finished tomato products.

## Estimated Demand for Tomato Products

Estimated demand constant variables influence throughput auxiliary variables, which in turn determine sales volume auxiliary variables. Product throughput for all simulations is processed at 80% capacity utilization (Senechal, 1997) (Rufer, 1997). The validation simulation

[1]To set the simulation time of the model click simulate on the menu toolbar, select simulation setup, click on stop time and set the number of days representing season length.

uses an average capacity utilization of 93% (Senechal, 1997). The demand for paste product is set initially at 100% and diced tomato product at 0% of raw product processed. Each simulation following increases the amount of diced tomato production by 10% and reduces the amount of paste production by 10% of raw product processed, Table 1.

**Raw Requirements**

Once a tomato processor has estimated the demand for finished product, raw tomato product requirements to meet this demand must be established. The constant and auxiliary variables used to compute processor raw product requirements and the required processor raw input capacity are displayed, Figure 4.

**Table 1. The Effects of Product Mix (31° Brix Tomato Paste and Diced Tomatoes) on the Profitability of a Potential Ohio Tomato Processor.**

| ROI | ROE | Net Income | % Diced | % Paste |
|---|---|---|---|---|
| -27.30% | -84.00% | -$12,111,648.00 | 0 | 1 |
| -17.00% | -58.00% | -$8,392,741.00 | 0.1 | 0.9 |
| -5.70% | -30.10% | -$4,339,275.00 | 0.2 | 0.8 |
| 5.00% | -3.10% | -$455,213.00 | 0.3 | 0.7 |
| 15.80% | 23.80% | $3,435,771.00 | 0.4 | 0.6 |
| 26.50% | 50.60% | $7,289,552.00 | 0.5 | 0.5 |
| 37.40% | 77.80% | $11,204,165.00 | 0.6 | 0.4 |
| 48.30% | 105.00% | $15,124,751.00 | 0.7 | 0.3 |
| 58.80% | 131.30% | $18,908,695.00 | 0.8 | 0.2 |

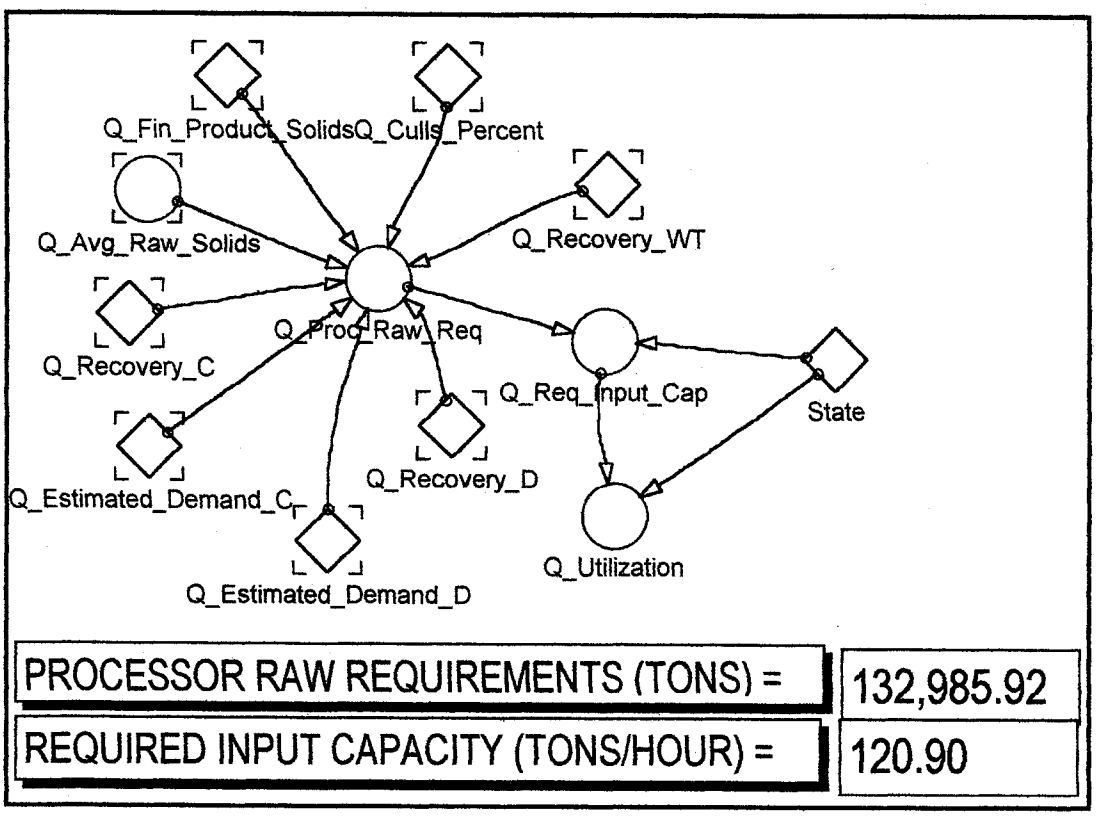


**Figure 4. Flow Diagram Illustrating Constant and Auxiliary Variables Used to Compute Processor Requirements of Raw Tomato Product and the Required Raw Product Input Capacity.**

Computing raw product requirements for a tomato processor requires considering the amount of finished tomato product produced; the soluble solids content of the finished tomato product; the average soluble solids content of raw product processed; the processor recovery; and the percent of raw supply that makes up culls.

Knowing the processor raw requirements allows an analyst to compute the required raw input capacity of the plant. An auxiliary variable represents processing plant utilization efficiency. The input capacity of the plant is 130 tons per hour.

**Soluble Solids Content**

The soluble solids content of tomato products varies. Total solids and water compose raw tomatoes. The production of many tomato products involves the removal of water from tomato product and the subsequent concentration of the total solids. Concentrated tomato products are often manufactured with solids in excess of 40% (40° brix). Due to the time consuming methods of measuring total solids content, the soluble solids content of the tomato or degree brix is measured. This provides an appropriate estimation of total tomato solids from the field (Gould, 1992).

The product mix simulations in this report use a soluble solids content of 31° brix for tomato paste. Senechal et al.'s study looked at a process that produces paste solids ranging from 16° brix to 46° brix for tomato paste. The study generates processor requirements using a 46° brix figure, which seems excessive when the industry standard solids for tomato paste is 31° brix. Senechal et al. use a market price, which appears very similar to that fitting for a recent market price for 31° brix. Finished tomato product soluble solids content is controlled by a constant variable.

**Production Quantities of Finished Tomato Products**

PowerSim constructor maps the flow of tomato paste production already mentioned earlier in this report. The flow of tomato paste follows a common set of steps, Figure 5. The processing rate is determined by the daily supply rate into the plant, through the plant's level variables beginning at the entry stage, sorter, chopper, preheater, extractor, and evaporator, coming out the other end as finished concentrated tomato paste. The use of stocks and flows to represent the different stages in the process allows an operator to monitor production over time. Flow rates represent the daily rate of product flowing through the processing plant.

An auxiliary variable is used to ensure that the raw product used for processing concentrated product is diverted into the concentration process, while the raw product required to meet the expected demand for diced tomatoes is pushed through the diced tomato production process.

The amount of paste produced as a percent of raw product processed is determined by the ratio of raw product required for concentrated product to raw product for diced tomatoes. To ensure the processor only pays for useful raw product and not culls, culls are extracted during the sorting process before going through the chopper. A constant variable represents the culls percent of total raw product supplied. An auxiliary variable represents the total amount of raw tomatoes actually paid for by the tomato processor.

As product flows through the plant, the initial quantity of raw product supply is decreased by the culls percentage and the recovery rate in the plant. Tomato solids are concentrated to a level desired by the processor. The concentration of processed tomatoes into finished product depends on the concentration desired, and the average soluble solids of the raw tomatoes processed.

The amount of raw tomato product for dices is determined by the auxiliary variable, which in turn depends on the quantity of concentrated tomato product, that the processor wishes to produce as a percent of total grower supply.

A flow rate determines the daily rate of raw tomatoes processed into dices. Levels represent the processing stages of diced tomato production. These stages are plant entry, quality sorting, chopping, canning and cooking. The culls percent of raw tomato product intake and the recovery rate of dices in the tomato plant can have a profound effect on quantity of finished tomato product produced and therefore processor ROI. A constant variable is the recovery rate for diced tomato production and is set at 80% for all simulations. An auxiliary variable determines final quantities of diced tomato production for a season.

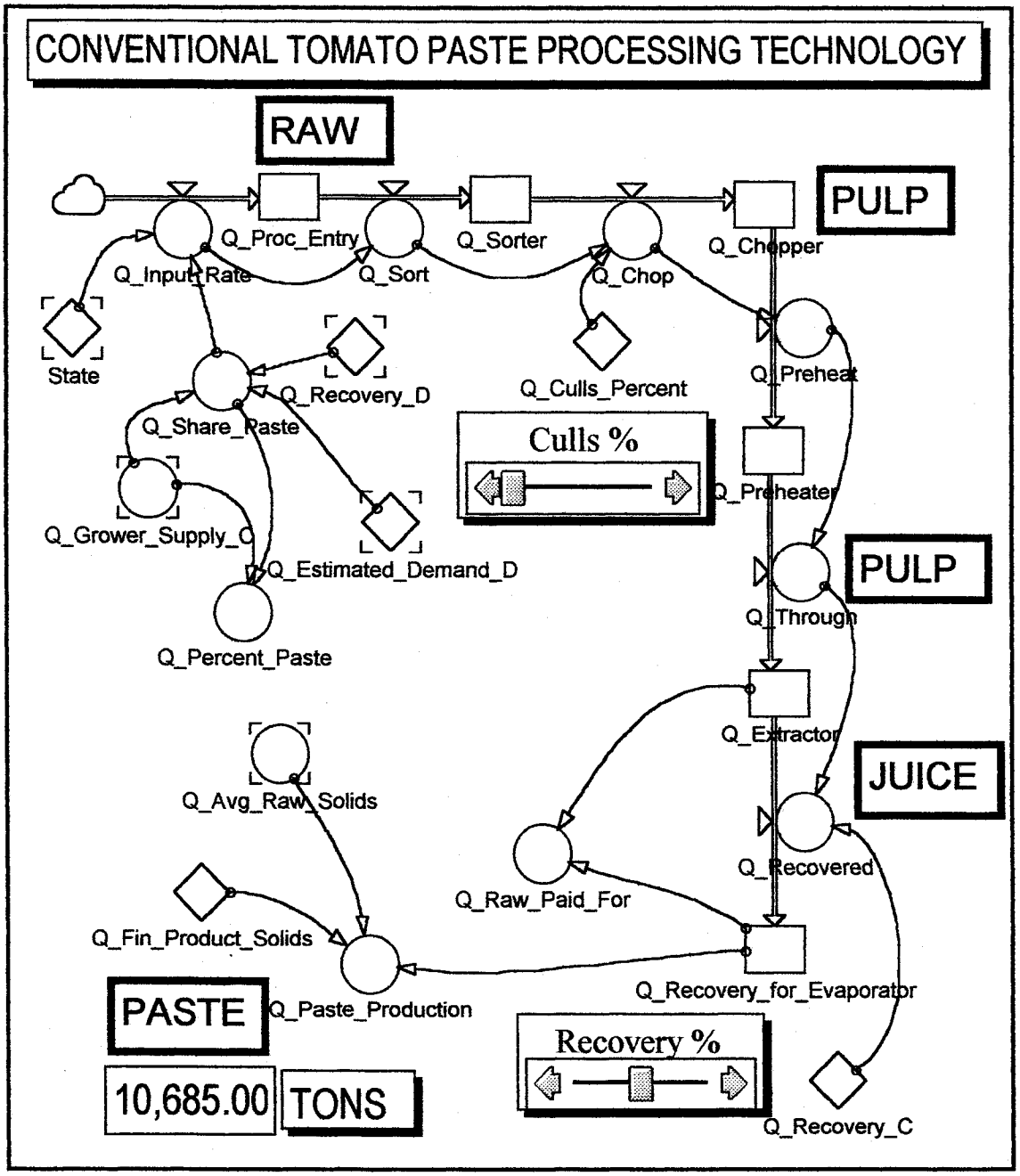


**Figure 5. PowerSim Flow Diagram Illustrating Production of Tomato Products Using Conventional Tomato Paste Processing Technology (Gould, 1992).**

**NTSS of Raw Product**

The importance of raw tomato solids content to the viability of producing concentrated tomato products using any processing technology can never be overstated. The relatively high solids content of raw tomatoes in California has been an important factor in establishing California's comparative advantage in tomato paste production. Average soluble solids content in California in 1999 was 5.13° brix (PTAB, 2000), while Ohio's four-year (1996-1999) average tomato soluble solids content is 4.14° brix (Francis, 2000).

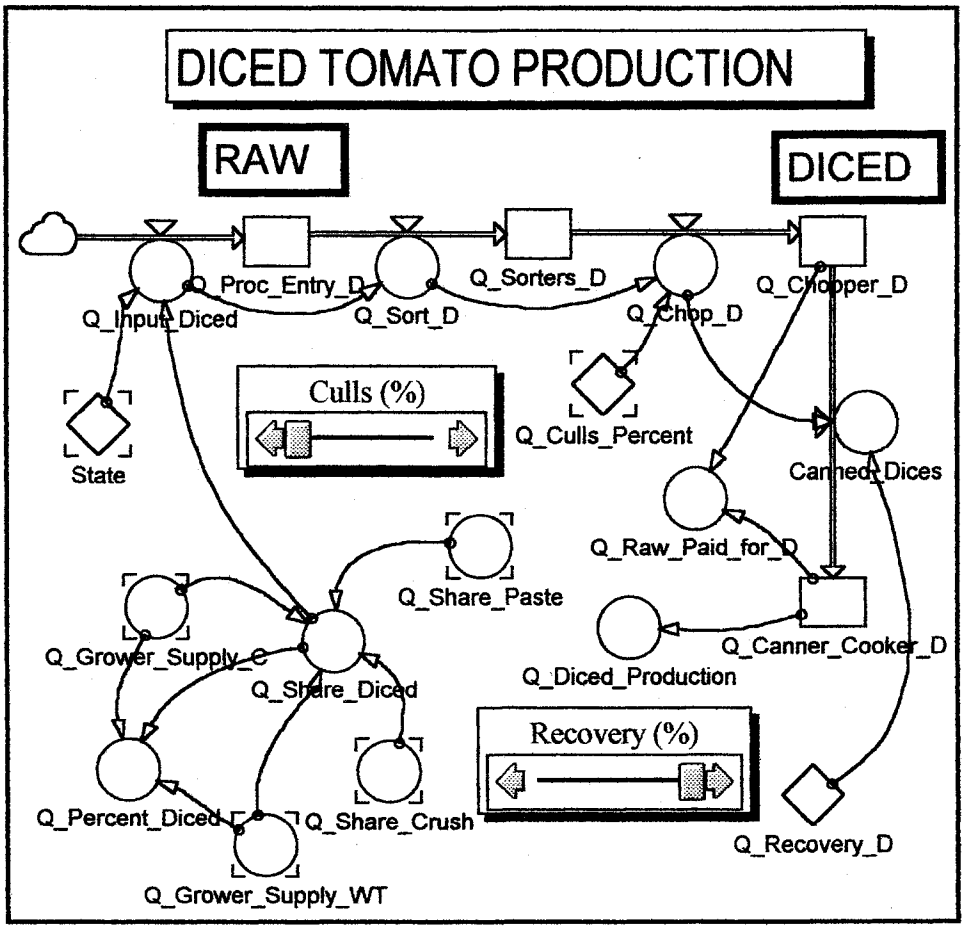


**Figure 6. PowerSim Flow Diagram Illustrating the Process of Producing Diced Tomatoes.**

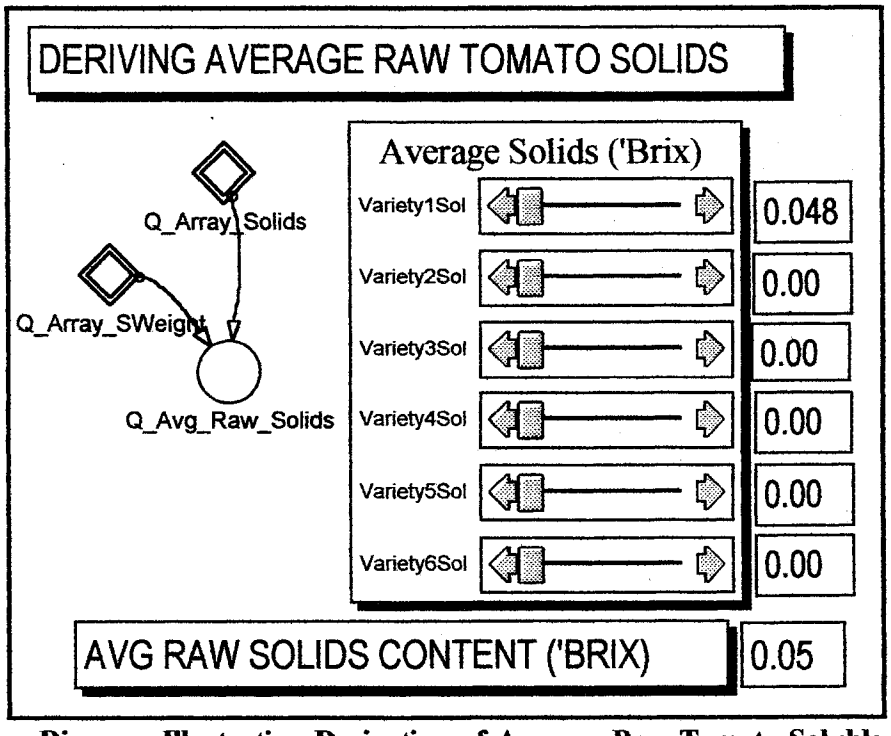


**Figure 7. Flow Diagram Illustrating Derivation of Average Raw Tomato Soluble Solids Content.**

An auxiliary variable represents the average raw tomato soluble solids content of tomatoes processed. Arrays are used to enable the model operator to enter different soluble solids content figures for different tomato varieties processed. The solids content for each variety is attached to a slider to vary according to the desire of the operator. An array represents the percent of each variety supplied to the plant, while elements of a separate array represent the individual average soluble solids content of each variety processed.

**Price of Finished Products**

The critical variables controlling the influences of finished tomato product pricing on the rest of the model are constants. As mentioned in the literature review, the market price for 31° brix tomato product quoted and recorded by various organizations and analysts is the market price for U.S. grade A product packed for open sale (CTGA, 2000). All simulations use an expected price drawn from a distribution of average U.S. Grade A prices for analysis.

A constant variable represents the market price for U.S. grade A paste. Although processors do sell tomato paste according to factors such as viscosity, mold and product age, these factors are not included in the model.

The constant variable P_Diced_Price represents the market price for diced tomatoes. Due to lack of historical data, Senechal et al.'s figure of $520/ton is used as the expected market price of diced tomatoes. The diced tomato price is drawn from a normal distribution. The diced tomato price distribution assumes a standard deviation of $20/ton.

**Optimal Product Mix Results**
**ROI and ROE Computational Methods**

All potential product mixes influence return on investment (ROI) and return on equity (ROE) (Figure 8). Auxiliary variables represent the return on investment and the return on equity for a proposed tomato processing plant over the course of one average processing season in the late 1990s. ROI is income before interest divided by average total assets. ROE is net income divided by total equity.

ROI increases as income before interest increases or as average total assets declines. ROE increases as net income increases or as total equities invested in the product declines. Average total assets are defined as all probable future economic benefits obtained or controlled by a particular entity (in this case grower-investors) as a result of past transactions (Weil, 1994).

The processing plant input capacity determines total processor assets. Processor required input capacity is determined by the amount of raw product required by the processor divided by the number of days in the processing season divided by the number of hours worked in the plant each day. As raw input capacity increases, average total processor assets increase at a decreasing rate. For this research project the average total processor assets are $36,000,000[2] for an Ohio tomato processor with a raw input capacity of 130 tons per hour operating at 80% utilization. Auxiliaries represent shareholder equity in the tomato processing plant and the ts the total debt incurred by the processor. The value of processor average total assets and the ratio of debt to equity determine both of these variables. A constant variable represents the ratio of debt to equity. The simulated tomato processor has a debt to equity ratio of 60% debt, 40% equity, or a ratio of 1.5. The cost of processor debt is determined by the interest rate, set at 10.5% for all simulations. The values of debt-to-equity and interest rate vary as desired when simulating in PowerSim Constructor 2.5.

An auxiliary computes net income as income before interest minus the cost of debt. Net income increases as the cost of debt decreases or as income before interest increases. Income before interest increases as total revenues increase relative to total costs. An auxiliary computes the total revenues generated from the sales of all tomato products in the model's average processing season. Total revenues increase with higher final product prices and higher final product sales volumes. Total operating costs are also represented by an auxiliary, increasing as either expected product costs or expected other operating costs increase. Expected raw product costs are determined by the quantity of raw product bought from tomato growers multiplied by the Free on Board plant price paid to tomato growers.

[2]Based on Senechal et al. (1997) recommendations for Ohio plant.

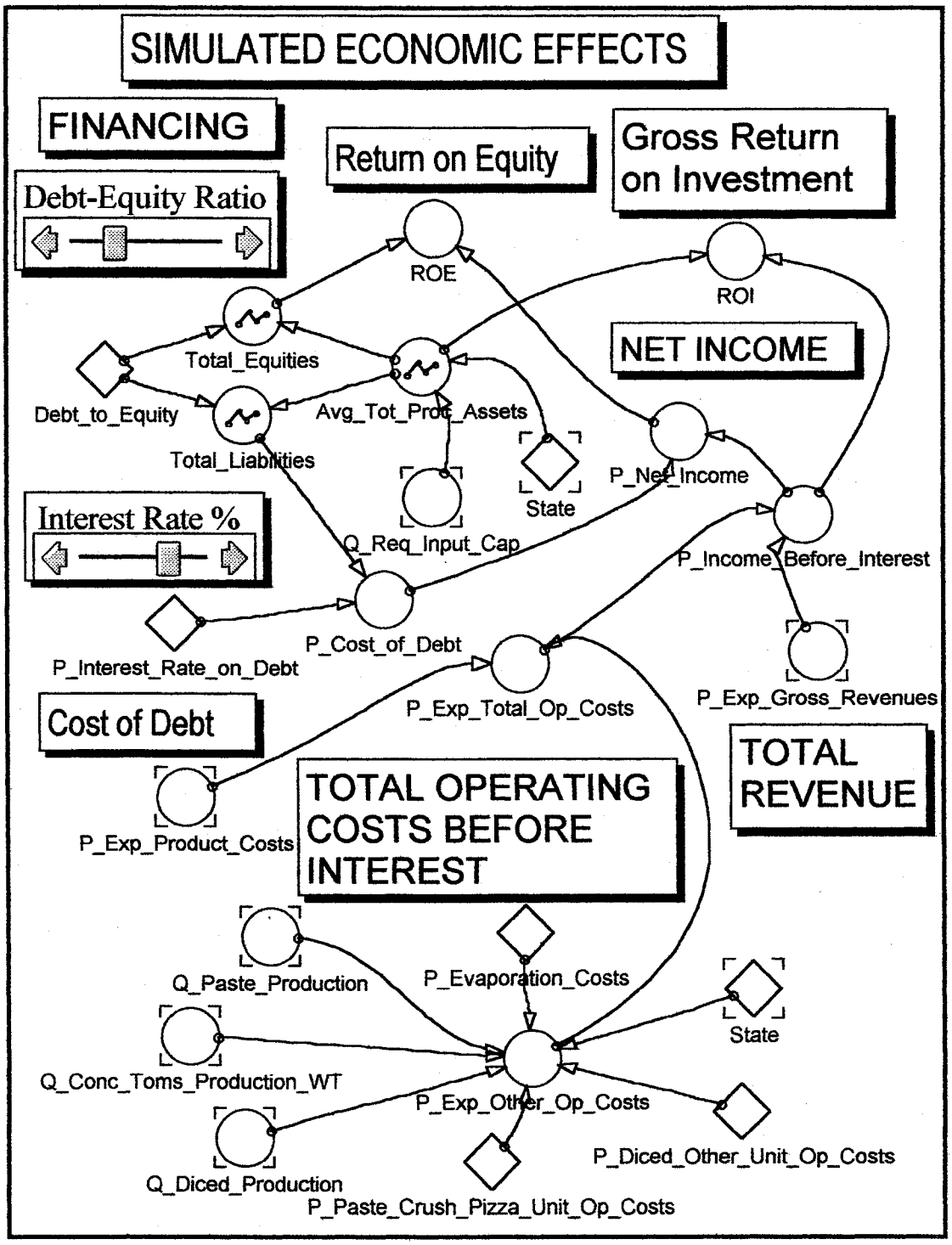


**Figure 8. Flow Diagram Illustrating Immediate Factors Involved in the Simulation of Economic Effects, Specifically Return on Investment and Return on Equity.**

**Model Validation**

The Tune task in PowerSim Solver was used to validate the model. Averages were taken from Senechal et al. data and used in the validation simulation. The simulated total processor raw product requirements of 132,985.8 tons per season is an almost perfect reflection of the 132,986 tons of raw product established as Senechal et al.'s processor raw product requirements. The ROI established from the validation simulation was 12.5%, which is within the typical range of ROI figures established by Senechal et al., of 12.1% to 15.2%.

**ROI and ROE Results**

Diced tomatoes are more profitable than 31° brix tomato paste, Table 1 and Figure 9. As more raw product is used for the production of diced tomatoes rather than concentrated tomato paste, less tomato soluble solids are required to manufacture a similar or greater output. This means that less raw product in general is required to produce more finished product. Increased volumes of output produced for the same amount of raw product processed results in lower total operating costs per unit, higher profit margins and therefore higher ROI and ROE.

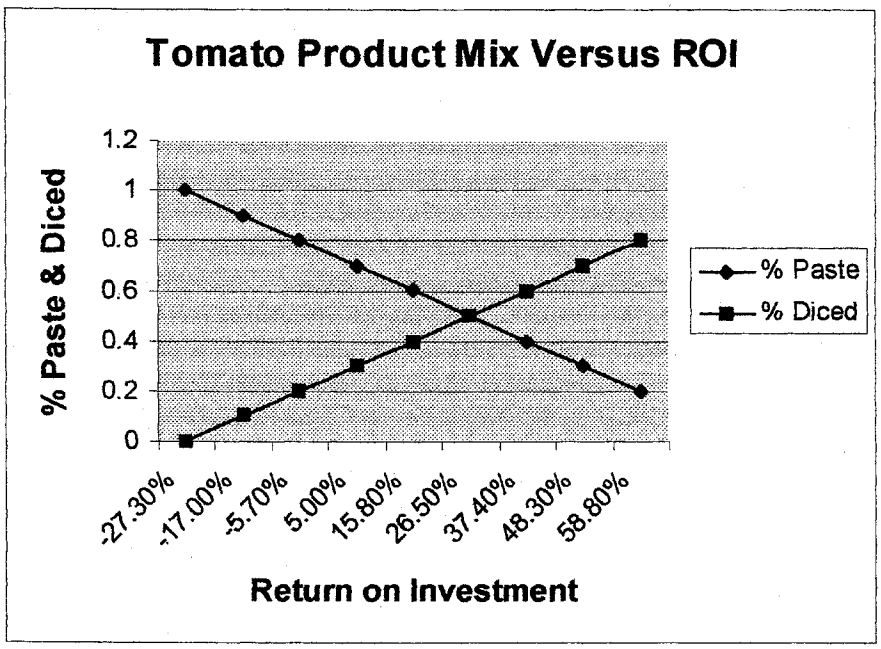


**Figure 9. Effects of Product Mix (31° Brix Tomato Paste and Diced Tomatoes) on the Profitability of Tomato Processing.**

**Conclusions**

Economic simulation modeling is an effective way of evaluating management decision-making in tomato processing plants (Starbird & Ghiassi, 1986). Clearly, the concentration of finished tomato product produced and the reliance of finished tomato products on NTSS to increase finished product output is critical in determining the profitability of a potential tomato processing plant, particularly in Ohio.

The optimal ratio of diced tomatoes to 31° brix tomato paste ranges between 40% and 60%. At this ratio the processing operation generates an ROI of 15.80%, an ROE of 23.8% and net income of about $3.4 million per year. A product mix of 50% diced tomatoes to 50% tomato paste (31° brix) achieves a processor ROI of 26.50%, ROE of 50.60%.