Raw Material Management at Welch's, Inc.

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Welch's, a large grape-processing company owned by a grower cooperative, faced complex logistics in planning recipes for products sold in retail stores. The recently installed integrated MRP and cost-accounting systems did not include ways to calculate recipes at optimal cost based on plant-raw-material and capacity constraints. An imbalance of supply and demand further complicated this problem in raw-materials management. The cross-functional team in charge of managing raw materials spent increasing amounts of time deciding what recipes to use at each plant. We formulated the problem as a linear program model and used spreadsheet optimization to incorporate the model in daily decision making. The company has run the model each month since 1994 to provide senior management with information on the optimal logistics plan. This simple application saved Welch's between $130,000 to $170,000 during the first year.

Welch's, Inc. is the world's largest processor of Concord and Niagara grapes with annual sales surpassing $550 million per year. Founded in 1869 by Dr. Thomas B. Welch, the company now produces a variety of fruit-based products for distribution in domestic and international markets. Such products as Welch's grape jelly and Welch's grape juice have been enjoyed by generations of

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American consumers.

Welch's has the largest share of the market in non-citrus frozen concentrates sold at retail stores. Within this product group, it sells 100 percent grape-juice concentrates and many blended-juice concentrates, including a line of cranberry-based products. In this retail category, Welch's has greatly increased shipments during the past 15 years.

Welch's is the production, distribution, and marketing arm of the National Grape Cooperative Association (NGCA) headquartered in Westfield, New York. The membership of the NGCA includes 1,400 growers who cultivate 41,000 acres of vineyards clustered in the northern parts of the United States. The members of the NGCA produce Concord and Niagara varieties of grapes. The Concord grape variety is purple in color and is grown in the cooler regions of the United States. The Niagara grape variety is light in color and also is grown in cooler climates. Major growing areas for Concord and Niagara variety grapes include western New York, northern Ohio, and northern Pennsylvania (all three near Lake Erie), western Michigan, and south-central Washington.

NGCA owns Welch's outright; it acquired the company from private investors in 1954. Members of the cooperative receive profits from Welch's as a premium above the open-market value of grapes. NGCA requires all members to sign a perpetual contract committing fixed amounts of Concord and Niagara acreage to Welch's and agreeing to deliver all the grapes grown on that acreage to Welch's. If they wish, growers can sell their contracts to others who want to enter NGCA.

Climate and cultural practices influence the yield per acre for grapes. As a result, Welch's must deal with wide swings in the total size of the Concord and Niagara crop each year. The security of a consistent market for grapes in times of surplus and shortage provides strong incentives for growers to join NGCA.

Welch's operates raw-grape-processing plants near the growing areas of NGCA members. During harvest, the plants process raw grapes into juice. Each plant also produces bottled juices, jellies, jams, and frozen concentrates for retail sale. The plants represent a pure form of vertical integration in agribusiness since they handle all the steps from pressing grapes into juice to distributing finished products. In total, the plants process nearly 300,000 tons of grapes per year.

The food-processing industry must deal with dynamic demand for finished goods and with customers' requirements for good service. To do this, Welch's holds finished goods inventory as a buffer against fluctuating customer demand. Over the past 12 years, Welch's has developed several methods of production planning [Allen, Martin, and Schuster 1997; Allen and Schuster 1994; Schuster and Finch 1990].

Welch's also maintains a large raw-materials inventory stored as grape juice in refrigerated tank farms. Managing these raw materials is an interesting planning-and-control problem.

The Harvest Process

Every September, growers under contract to NGCA begin delivering grapes to processing plants located in their region. During a span of about 40 days, the plants press raw grapes into juice. Welch's pasteurizes the fresh juice and stores it in refrigerated tank farms. Packaging operations at each plant run at a steady pace all year long and draw juice from the tank farms as needed to support production. The value of the grape juice stored in the tank farms often exceeds $50 million per year based on cash market value.

Time must pass before the grape juice is ready for conversion into finished jams, jellies, juices, and concentrates. Raw grape juice contains insolubles that slowly settle to the bottom of the tank. After this settling process, the juice is ready for use in the production of finished goods.

Some of Welch's products require concentrated juice. Concentration adds another step beyond the settling process. From the time of harvest, it takes several months to obtain concentrated juice (Figure 1).

The annual grape harvest varies a great deal in size depending on the spring and summer weather. Welch's takes all grapes grown on acreage contracted to NGCA. Because weather has an impact on the yield of grapes per acre, the exact size of the grape harvest is never known until the end of harvest when all grapes are picked. Although each grower is subject to rigid quality standards, differences in sweetness, color, and acidity do exist among growing areas. Weather also plays an im-

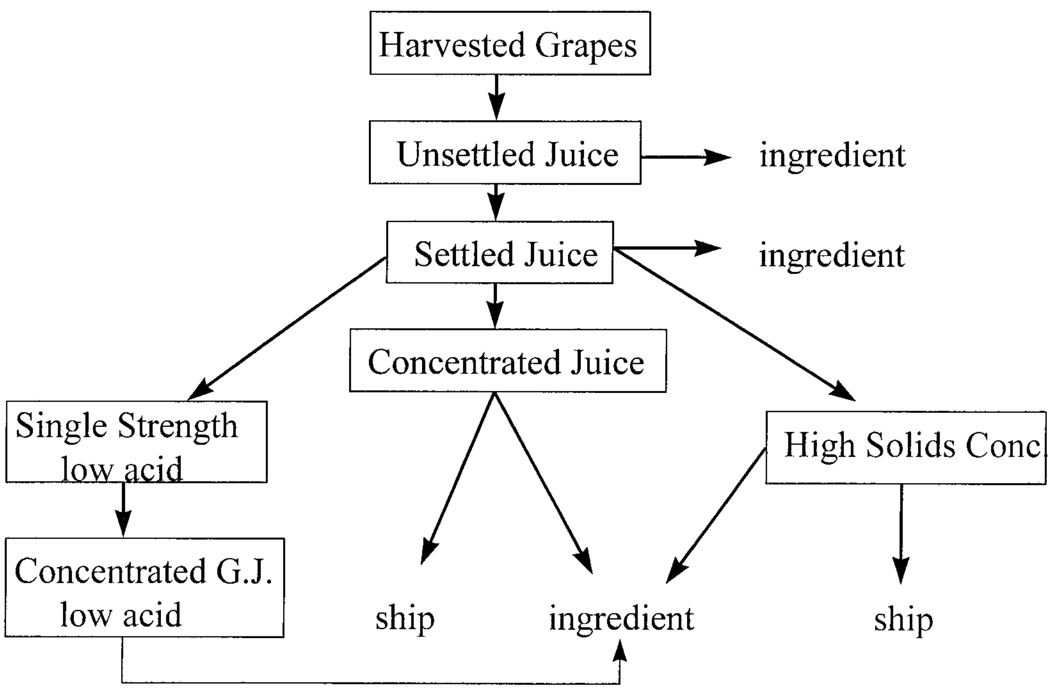

Figure 1: In processing grapes into grape juice and end products, Welch's goes through several steps: (1) unprocessed grapes are pressed into single strength juice that is unsettled; (2) after a period of time passes, insolubles settle to the bottom of the tank and settled juice results; both settled and unsettled juice is used directly as ingredients; (3) settled juice is either concentrated or undergoes further processing; concentrate is used as an ingredient or is shipped as a finished product to bulk customers.

portant role in year-to-year crop differences in quality. As a result, supply, demand, and quality are seldom equal for all growing areas. Welch's takes pride in making products with consistent taste despite crop variability between growing areas and from year to year. To maintain a national consistency, Welch's often transfers juice for blending between plants.

The Common Planning Unit

Welch's uses "tons" as the base unit of aggregate planning in materials management. A "ton" represents the amount of grape juice obtained from pressing one ton of grapes. Different growing areas may produce grape juice that has different levels of sweetness. To calculate a common inventory unit for grape juices of different sweetness, Welch's uses instruments called refractometers [Gould 1977, p. 78] to find the *percent of water soluble solids* (%WSS) of different lots of grape juice. Using this measurement, it calculates pounds of fruit solids (#FS) using a standard table that converts volume (gallons) and %WSS into #FS. It is #FS that becomes the base inventory unit for Welch's accounting systems. As juice is concentrated and reconstituted, %WSS may increase or decrease, but #FS remains the same for an initial amount of grape juice. The Food and Drug Administration (FDA) sets forth rules called the standard of identity that ensure juice is reconstituted to a set level of %WSS. This protects consumers by preventing companies from adding excess water to concentrate.

The plants process nearly 300,000 tons of grapes per year.

To simplify communication, Welch's converts #FS into tons by using factors obtained during the harvest that determine the yield of #FS per ton of grapes processed at a specific plant. Some groups within Welch's and NGCA find it hard to understand the #FS unit of measure for inventory and demand of grape juice. By converting #FS into tons, Welch's achieves a universal physical unit of measure that everyone understands. Members of NGCA receive payment based on how many tons (or #FS) of grapes they deliver to Welch's. In turn, Welch's determines the profit per ton (or #FS) sold as finished product in a given month.

Welch's has a refined cost-accounting system that calculates requirements for Concord and Niagara grapes by month in #FS and tons. The system accounts for the recovery loss and the cost of converting Concord and Niagara grapes into finished product. In June 1996, the company implemented a fully integrated material requirements planning (MRP) system that calculates time-phased requirements for all components needed to manufacture finished products. The new MRP system takes advantage of relational-database-information technology and operates in real time rather than in batch mode. The new, minicomputer-based cost-accounting and MRP systems also allow for extraction of data to computer spreadsheets. Yet, both these systems have two major drawbacks: (1) they assume infinite capacity and do not consider operational constraints in MRP calculations, and (2) they do not provide optimal cost solutions for blending juices.

Since most large-scale MRP systems do not consider capacity or material constraints, it is hard to obtain even nonoptimal solutions to blending and logistics problems. The Welch's MRP system uses regenerative MRP logic. To make even minor changes to bills of material, Welch's must make a complete run of the MRP system to obtain new net requirements for grape juice. The Welch's MRP system takes about six hours per run. This virtually eliminates the possibility of using it to interactively find nonoptimal solutions.

The Juice-Availability Committee

Deciding how to use the grape crop is a complex task given changing demand and uncertain crop quality and quantity. To deal with this situation, in 1984 Welch's established a cross-functional committee that would be responsible for making decisions on crop usage, the juice-availability committee (JAC). Its members come from staff and line departments within Welch's. The JAC has representatives from cost accounting, quality assurance, research and development, engineering, plant operations, and logistics. Every month the committee meets to discuss crop-usage strategy with the goal of minimizing total system cost within constraints set forth by plant operations.

Typical decisions concern

(1) What recipes to use for major product groups,

(2) The transfer of grape juice between plants,

(3) The control of carryover to ensure enough room for the next crop,

(4) The financial impact of recipe and transfer decisions, and

(5) The mode of transportation (rail or truck) to use for transfers of juice between plants.

The JAC makes decisions based on information from existing cost-accounting and MRP systems. Both of these systems need the input of a set of recipes to calculate grape requirements. Welch's has a staff of research scientists trained in food technology who find the best recipe to satisfy consumer taste. In most situations, a range of recipes will be acceptable to the consumer. Some recipes may contain grape juice bought outside the cooperative. Juice from other varieties of grapes is often blended with Concord or Niagara juice. This gives Welch's additional flexibility in balancing supply and demand when there is a short grape crop. Given a group of feasible recipes, the JAC must choose the set of recipes for each plant that minimizes total cost and meets operational constraints.

Historically, the JAC made its recipe decisions after intense discussion. Trial-and-error methods guided thinking about the best set of recipes to use. Computer spreadsheets often served an important role in what-if analysis. However, it would take many iterations to arrive at a feasible plan by simultaneously adjusting recipes and the amount of grape juice to be transferred between plants.

Welch's lacked a formal system for optimizing raw material movement and the recipes used for production. The operations management literature shows several solutions for this problem [de Matta and Miller 1993; Liberatore and Miller 1985; Markland and Newett 1976]. Several of these solutions build on the models of hierarchical integration set forth by Hax and

Meal [1975]. The work of these authors becomes critical to planning in the process industries because of their treatment of capacity. Taylor, Seward, and Bolander [1981] note that process industries tend to schedule capacity first and then materials. The existing cost-accounting and MRP systems at Welch's lacked the ability to consider such elements of capacity as rates of concentration and capability of transporting grape juice between plants. Within the context of capacity, Welch's needed systems that would consider a wide set of feasible recipes and take into account the timing of the availability of juice from the new crop.

Welch's faced a difficult problem in juice logistics.

To improve the cost-accounting and MRP systems, we developed a third model that works independently but draws data from the cost-accounting system. Both the cost-accounting and MRP systems calculated requirements for grape juice correctly, but each lacked the ability to calculate optimal-cost recipes and interplant transfer schedules based on the operational constraints at each plant. Without consideration of operational constraints, the output from the cost-accounting and MRP systems was of little practical use to the JAC in making decisions on how best to use the grape crop. Wider use of inaccurate outputs from the cost-accounting and MRP systems caused additional problems in forecasting financial performance and managing the purchase of juice outside the cooperative.

In employing a third model, we envisioned a recursive solution method in which the existing cost-accounting system initially acts as a database, providing information on grape juice demand to the third model. In turn, the third model calculates optimal recipes and interplant transfer schedules based on operational constraints and cost. After it completes this calculation, the optimal recipes are input into both the cost-accounting and MRP systems. The next output of both these systems will then reflect an optimal cost plan and a set of recipes that meets operational constraints. All downstream users of the cost-accounting and MRP systems, other than the JAC, also receive benefits from having system outputs that reflect an optimal plan for grape juice logistics.

When choosing a recursive method to find solutions, it is important that the inputs and outputs passing between steps in the calculation be accurate. The cost-accounting and MRP systems at Welch's use a single, detailed bill of material (BOM) for each recipe. Welch's audits critical BOMs once per month. This provided a high degree of confidence that the initial output concerning grape juice demand from the cost-accounting system would not provide false data to the third model.

As we began to think of a mathematical formulation of the third model, one difficulty remained. The managers at Welch's had little desire for mathematical models. A tradition existed that decision making should not rely on models but rather on consensus of the management group. Few active models for decision making existed at Welch's.

The First Solution

In the fall of 1992, Welch's faced a difficult problem in juice logistics. The Eastern 1992 crop was high in acid and low in yield. It was not possible to meet product specifications for acidity using the materials at hand, so the JAC faced the complex logistics of blending large amounts of juice at several plants to maintain quality. The company could obtain low-acid grapes from sources outside NGCA to blend with the high-acid crop. The JAC had to decide how much low-acid grape concentrate to buy.

After observing the problem, we developed a preliminary linear-programming (LP) model. The model focused on the component level of detail and provided recipes that minimized cost and met operational constraints. The formulation became the juice logistics model (JLM). Small-scale testing proved that the model worked.

The formulation used monthly time buckets and a one-year horizon (8,000 decision variables). A long time horizon is necessary to plan recipes for an entire crop. If needed, recipes can change within a range during each month of the year. However, the overriding goal is to minimize month-to-month recipe deviations so that consistent taste results.

It takes Welch's about one year to sell a crop. A key factor in determining the rate at which to sell the crop is the amount of carryover to have available pending arrival of a new crop. If carryover is too low, not enough juice exists to meet consumer demand until the new crop becomes available. Traditionally, Welch's increases its prices when faced with this situation, hoping to slow demand in time to extend carryover. However, in the food-processing industry demand is elastic for finished goods sold to customers. Even small increases in price have drastic impacts on demand. Complicating matters, retailers often drop items soon after manufacturers announce a price increase. To regain distribution, retailers require payment of a slotting allowance before restocking the item. On a national basis, these fees could amount to millions of dollars in extra expense in the event of a shortage of grape juice. The threat of slotting allowances gives good reason to maintain an adequate year-to-year carryover of grape juice.

After reviewing the JLM, management was hesitant to implement the model. Few senior managers at Welch's understood the fundamentals of LP. The lack of understanding raised questions concerning the need for a third mathematical model beyond the existing cost-accounting and MRP systems to improve the management of grape-juice inventories.

A Revised Juice Logistics Model

We believed that Welch's needed the JLM, and we looked at other ways of implementation. The original JLM required software capable of handling large-scale LP problems. Senior management expressed concern about the maintenance requirements of LP software. Examining alternatives, we found that spreadsheet software (What'sBest!) could handle large LP problems at a reasonable cost. Spreadsheets provided a natural interface for end users to see the benefits of management science and model building [Leon, Przasnyski, and Seal 1996; Plane 1994; Winston 1996].

It quickly became clear that the original

JLM (8,000 variables) was much too large for a spreadsheet application. The version of What'sBest! that we purchased handled 4,000 variables and 2,000 constraints. Though larger versions of What'sBest! exist, we thought that managing 8,000 decision variables in a spreadsheet with constantly changing coefficients was untenable. We decided to reduce the size of the problem to reduce data requirements. Finch and Cox [1987, p. 6] observe that most process-oriented firms have a V-shaped bill of material with a few raw materials making up a large number of end items. With this in mind we decided to use product families to simplify the JLM.

Three product groups account for the majority of grape-juice requirements at Welch's. For example, Welch's sells 64-oz and 24-oz bottled purple juice. Both of these items are in the purple-juice product group and use the same recipe. In our revision of the JLM, we aggregated demand by product group rather than by component. This greatly reduced the number of decision variables. The new JLM (appendix) has 324 decision variables and 361 constraints.

The aggregate-demand information for grape juice comes directly from existing cost-accounting systems. The current systems calculate total requirements for grape juice by month. The JLM determines what percentage of the total requirement comes from patron (NGCA) sources based on recipe and supply constraints and cost minimization. This is a less detailed approach than calculating demand by component.

Some authors raise concerns about the risks of planning with inventory and demand expressed in aggregate terms [de Matta and Miller 1993, p. 119]. A firm may have excesses or shortages of inventory at the end-item level while appearing to have adequate inventory at the aggregate level. Inventory excesses or shortages at the end-item level often balance each other out when viewed in aggregate terms. This might produce a misleading view of the overall inventory situation, causing difficulties in planning production of end-items when using product-family disaggregation methods. Although this may be true for production planning of finished goods, we found the product-family structure of the JLM to work quite well in material planning.

The Juice Logistic Model

The JLM is an application of LP to a single-commodity network problem. The decision variables deal with the cost of transfers between plants, the cost of recipes, and carrying cost—all costs that are key to the common planning unit of tons. The objective is to minimize cost and still be able to meet operational constraints.

The use of carrying cost within the JLM bears a special note. Upon harvest of the grapes, NGCA makes a cash payment to growers called a preharvest advance. Growers continue to receive payments on a quarterly basis until the crop is completely sold. The cost of grapes, valued at open market prices, is sunk cost at the time of harvest. Welch's has a fixed investment in tank farms to store the juice and records only extra cost when a high carryover exists at the time of new crop harvest.

A high carryover means there may not be enough space for the new crop. In this case, Welch's must pay extra money for space-making operations that may include temporary rental of additional tanks from other processors. To reflect this situation in the JLM, we add a carrying cost for the end of the crop cycle (month 12) that includes the incremental cost of carrying extra inventory beyond the new crop harvest (see constraint 2). In between harvests, the variable cost of storing grape juice at each plant is approximately the same. The geographical separation between Welch's bulk storage facilities is such that the cost of transporting grape juice between plants is greater than the variable cost of storage. This means juice seldom moves between plants unless an individual plant has a shortage.

The JLM proved an invaluable tool in planning between 1994 and 1996.

Tons shipped is the expression for demand. The research and development department sets maximum and minimum amounts of patron (NGCA) sourced grape juice as part of each recipe. In the JLM, given parameters *a* and *b* serve as the maximum and minimum percentages of patron grape juice content (see constraints 3 and 4).

The material balance (constraint 2) is a key part of the JLM. This constraint deals with inventory, tons shipped, and in-out transfers for a plant. The transfer balance (constraint 7) links raw-material movement between plants. With the recipe parameters *a* and *b* providing a range of possible recipes, the JLM chooses a single recipe for each product group that minimizes the cost of transfer, the recipe, and carrying inventory.

JLM Results

We began operating the JLM in the spring of 1994. Each month we ran the JLM and analyzed the results. The JLM provided a much more structured approach to planning for raw material usage than the previous methods of analysis. This reduced the time it takes to find the best recipes. By incorporating constraints dealing with plant capacity (such as constraint 6), the model produced plans that match actual conditions at the plants.

The output of the JLM acts as a communication tool for the JAC. An optimal solution, presented in standard format, becomes the official plan of action. We found that the JAC accepted the JLM only after we incorporated the model into meetings as a major discussion point. By shifting the JLM from being a special project to becoming an operational tool, the chair of the JAC gained gradual acceptance from other members of the committee. Our experiences very much parallel those reported previously [de Matta and Miller 1993, p. 120].

As crop or demand conditions change, the JAC reruns the JLM to find a new optimal solution. Our experience is that run times are very small (less than one minute on a 486, 66 MHz microcomputer). Welch's runs the JLM about 10 times per month.

The JLM proved an invaluable tool in planning between 1994 and 1996. In July 1994, Welch's had a chance to purchase some raw grapes on the open market. This opportunity occurs every year. The supplier of the grapes had sold to Welch's for several years. The JLM quickly showed that Welch's did not need the extra grapes.

Welch's saved between $130,000 to $170,000 in carrying cost by avoiding this purchase.

In the years 1991 to 1995, Welch's experienced a series of record-breaking grape crops. By 1995, year-to-year carryover was very high. Preparing for another record crop in 1996, Welch's used the JLM to model over 100 scenarios of different recipes and logistics costs in an effort to keep grape carryover under control. The JLM was very useful in generating new optimal solutions based on the assumption that the 1996 grape crop would be large. However, crop forecasts change very quickly as a result of weather conditions. A harsh winter and a late spring frost diminished the anticipated 1996 grape harvest to the lowest level in five years. Again the JLM provided a quick way to model the impact of the sharp loss in the grape crop. This allowed Welch's to adjust recipes rapidly so that it could meet demand without fear of running out of stock.

Conclusion

The JLM is a classic application of LP to an aggregate planning problem. It provides important information for a key decision-making committee with the responsibility of managing a large asset. We met several snags to implementation but were able to overcome these problems by reducing the problem size and using spreadsheet optimization. By formulating the JLM as a simple LP within a spreadsheet optimizer, we succeeded in explaining the model to people with different levels of mathematical understanding. In addition, those within Welch's gradually accepted mathematical-modeling principles as they used the JLM as a daily decision-making tool rather than a short-term, special project.

Building on the initial success of the JLM, we hope to develop a more comprehensive model that plans on a component level of detail and considers the change of material characteristics over time. This challenging problem has become of great importance to Welch's. We also plan to investigate different ways to assign costs and profit within the JLM. As we accumulate more experience with the JLM, new questions arise concerning the best ways to minimize cost and also to maximize profit.

Taking a broader view, the development of models like the JLM raises interesting questions about the role of cost-accounting and MRP systems within the process industries. Virtually every MRP system currently installed assumes infinite capacity when calculating net requirements and lot sizes for materials. In multiplant situations, similar to Welch's, logistics costs and capacity constraints remain important factors for consideration in MRP systems. Most process-oriented firms recognize the need for production-planning systems that consider capacity constraints; however, few have experimented with techniques to impose constraints on MRP using a recursive, third model approach. Our experience with the JLM, and its interplay with existing cost-accounting and MRP systems, leads us to conclude that third models can play an important role in planning and decision making. We believe this a practical area for future research.

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APPENDIX: The Juice Logistics Model

i = month, where $i = 1,2, \ldots I$,
j = product group, where $j = 1,2 \ldots J$,
k = plant, where $k = 1,2, \ldots K$.

Decision Variables:

$TS(i, j, k)$ = Grape juice shipped to customers in month i, for product group j at plant k (in tons),
$TI(i, k, m)$ = Grape juice transferred into plant k from plant m during month i (in tons),
$TO(i, k, m)$ = Transfers of grape juice out of plant k into plant m during month i (in tons),
$EI(i, k)$ = Ending inventory of grape juice for month i at plant k (in tons).

Costs:

$CT(i, k)$ = Cost of transporting grape juice in month i from plant k (cost per ton),
$CR(j, k)$ = Cost of recipe for product group j at plant k (cost per ton),
$CS(12, k)$ = Carrying cost of storing grape juice in month 12 at plant k (storage cost per ton).

Given Parameters:

$TU(i, j, k)$ = Total grape juice used (from NGCA plus juice from outside the cooperative) in product j at plant k in month i (input comes from the existing MRP system (tons)),
$a(i, j, k)$ = Maximum percentage of grape juice (from NGCA) in product group j for plant k in month i (percentage expressed as a decimal),
$b(i, j, k)$ = Minimum percentage of grape juice (from NGCA) in product group j for plant k in month i (percentage expressed as a decimal),
$MI(k)$ = Minimum ending inventory for plant k, where $i = 12$ (tons),
$OL(i, k)$ = Limit on outbound shipments for plant k in month i (tons),
$SL(k)$ = Limit on grape juice sold for plant k (tons),
$Ivalue(k)$ = Initial value of grape juice inventory at plant k (tons).
$C(i, k)$ = Crop received in month i at plant k (tons),

Objective Function:

$$\text{Min}\Big[\sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j=1}^{J} CR(j, k)TS(i, j, k) + \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{m \neq k}^{M} CT(i, m)TI(i, k, m) + \sum_{k=1}^{K} CS(12, k)EI(12, k)\Big]$$

Subject to

(1) Beginning inventory

$$EI(0, k) = Ivalue(k) \quad \text{For all } k.$$

(2) Material balance

$$EI(i, k) = EI(i-1, k) + \sum_{m \neq k}^{M} TI(i, k, m) - \sum_{m \neq k}^{M} TO(i, k, m) + C(i, k) - \sum_{j=1}^{J} TS(i, j, k) \quad \text{For all } i, k.$$

(3) Tons sold maximum recipe

$$TS(i, j, k) \leq a(i, j, k)TU(i, j, k) \quad \text{For all } i, j, k.$$

(4) Tons sold minimum recipe

$$TS(i, j, k) \geq b(i, j, k)TU(i, j, k) \quad \text{For all } i, j, k.$$

(5) Minimum ending inventory

$$EI(12, k) \geq MI(k) \quad \text{For all } k.$$

(6) Transfer constant

$$\sum_{m \neq k}^{M} TO(i, k, m) \leq OL(i, k) \quad \text{For all } i, k.$$

(7) Transfer balance

$$TO(i, k, m) = TI(i, m, k) \quad \text{For all } i, k, m;\ k \neq m.$$

(8) Tons sold constraint for each plant

$$\sum_{i=1}^{I} \sum_{j=1}^{J} TS(i, j, k) \leq SL(k) \quad \text{For all plants } k.$$

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Donald F. Biggs, Director of Logistics, Welch's, Inc., 3 Concord Farms, 555 Virginia Road, Concord, Massachusetts 01742-9101, writes: "Ed and Stuart worked together to develop the juice logistics model as an improvement to our juice management process.

"Since Welch's is a farm cooperative, management of raw materials (grapes) entrusted to us by our growers takes on great importance. We constantly deal with changes in supply and demand, and must know how these changes affect grape inventory. The model provides an excellent method to obtain quick answers to important questions asked by senior management. During the past several years of operation, the model provided keen insights to several significant problems. Decisions made after analysis of the model results contributed meaningful cost reductions.

"A brief example demonstrates the model's effectiveness. This past week Welch's faced a major change in the expected size of the 1996 grape crop. Several runs of the model led to a new set of recipes in response to the new crop estimate. The new set of recipes minimized transportation cost while maintaining established quality standards. The model accomplished these calculations in a fraction of the time previously required.

"Through the years, the use of applied management science has helped Welch's with a number of important decisions. The juice logistics model is one of several systems that contribute to strategic decision making."