POTENTIAL FOR EXPANSION OF THE WHEAT PROCESSING INDUSTRY IN OKLAHOMA

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Bachelor of Agricultural Sciences

University of Zambia

Lusaka, Zambia

1994

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1998

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ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my major Adviser, Dr. Phil Kenkel, for his intelligent supervision, constructive guidance, inspiration and friendship. My appreciation also extends to my other committee members, Dr. Francis Epplin, Dr. Dean F. Schreiner, Dr. Daniel S. Tilley, and Dr. Rodney Holcomb, for their invaluable guidance, assistance, encouragement, and friendship. I would like to thank Dr. Phil Kenkel, Dr. Rodney B. Holcomb, Dr. Daniel S. Tilley, the Department of Agricultural Economics and the Food and Agricultural Products Research and Technology Center for providing me with this research opportunity.

I also wish to express my gratitude to Dr. B. Wade Brorsen who provided very useful suggestions when optimization problems were encountered. My acknowledgements would be incomplete without mentioning Dr. Rolando Flores of Kansas State University for providing an electronic spreadsheet of his mill management economic model (MMEM), which was a major source of data on flour mill costs and input-output coefficients used in this study.

My gratitude also extends to the USAID/Zambia for providing financial support for my graduate program through the ATLAS Fellowship and to the African-American Institute for implementing the ATLAS project. Without this financial support, this undertaking would not have been possible. Invaluable thanks also go to my employers,

the Zambian Ministry of Agriculture, Food and Fisheries (MAFF), for all their support during my entire study program.

Finally, but not least, I wish to recognize all friends and family whose love and support helped me to accomplish this task. In particular, I am indebted to my wife, Doreen, who endured the two years of staying apart and a great deal of whining to help me reach my dream and to my daughter, Daliso, who was born and experienced her tender early life in my absence. Their long-distance love and the magnitude of sacrifice that we were going through as a family were a major source of inspiration and motivation for me to work harder every single passing moment. I also wish to express my sincere thanks to the family of my wife's sister, Mr. and Mrs. William and Gertrude Miko, for offering to stay with my family while I was away. Their care will always be remembered. Many thanks also extend to my parents, Mr. and Mrs. Alfred and Stelliah Tembo, for their long distance encouragement, support and love.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Wheat is one of the most important crops in Oklahoma and is planted on more agricultural land than any other crop (Oklahoma Department of Agriculture). Besides being a major source of revenue to farmers, winter wheat also provides excellent winter pasture opportunities for cattle. The unique growing conditions of Oklahoma, Texas and part of Kansas allow for most of the wheat that is grazed by cattle to also be harvested for grain. Hard-red winter wheat dominates Oklahoma production, representing nearly 99 percent of total wheat production.

Since 1992, Oklahoma wheat production has fluctuated from 93.1 to 168.2 million bushels (Oklahoma Department of Agriculture 1996). Part of the fluctuation in wheat production can be attributed to weather and growing conditions, while some is also due to the impacts of changes in government programs. While past government programs have provided incentives for farmers to plant and harvest wheat for grain, current programs are giving producers much lower incentives to plant and harvest program-supported crops like wheat. As a result, producers are considering more crop options, with decision-making being based upon the relative prices and production expenses of various commodities. It is possible that the mix of crops grown in Oklahoma will continue to change as farm programs phase out.

The current wheat milling industry in Oklahoma is comprised of four (4) major firms, one in each of the following locations ("X's" in Figure 5.4, presented later): Blackwell, Enid, Okeene and Shawnee. The four together have a total capacity of about 31,400 hundred weight (cwt.) of flour per day, which is equivalent to 942 million pounds of flour per year (Oklahoma Department of Commerce). This capacity represents less than 20 percent of Oklahoma's total wheat production, implying that more than 80 percent of the wheat produced in the state is exported as grain (Oklahoma Department of Commerce). The supply of wheat leaving Oklahoma as grain and high volumes of flour imports by Oklahoma bakers, along with recent migration of food processing companies into Oklahoma, have increased interest in developing additional flour mills in the state.

Divergent views are held by different authors regarding processing capacity expansion in the Great Plains states in general and Oklahoma in particular. Harwood, Leath and Heid argue that more urbanized and densely populated states tend to have comparative advantages in flour milling over Great Plains states such as Oklahoma. While wheat is usually shipped in large quantities, which could earn transportation cost discounts, flour and flour products are often shipped in small amounts for fear of high inventory and sanitation costs. Thus, it is relatively cheaper to transport wheat (not flour) over long distances and locate the processing plants near large demand centers. Empirical evidence shows that, although the total number of mills in the United States has shrunk from 279 in 1973 to 211 in 1987 (Kim, Lin and Leath), there has been widespread expansion of mill capacities during the same period, concentrated mainly in large demand centers (Harwood, Leath and Heid).

Milling potential is also likely to be affected by optimal location of storage. Benirschka and Binkley observe that producer prices decline with distance to markets due to increased cost of transport. They argue that, if markets are efficient, longer-term storage of grain such as grain reserves and carryover stocks will be located far from markets, implying that grain storage capacity increases with distance to market.

In recent years, changes in the United States' food industry seem to indicate that there could be a shift in the milling comparative advantages in favor of Great Plains states. Myers, for example, cites recent increases in relative population shares for the South and West as an important factor favoring milling industry expansion in the Great Plains.

In addition to the changes in consumer demographics, numerous changes in the nature of the demand for wheat products have also taken place. As with most foods in the U.S., more value is being added prior to when consumers actually purchase the food products (Barkema, Drabenstott and Welch.). Away-from-home food consumption has grown at a faster rate than total food consumption. The growth of restaurant chains and their demand for products that are easy to prepare on site have created a need for finished goods and frozen and refrigerated dough for breads, pizza crusts, and pastries that can be baked on site. These relatively higher-valued products can be produced at centralized locations and shipped to customers in a wide geographic area.

Of late, Oklahoma has been able to attract several firms that produce wheat flour-based products for regional and national distribution (Oklahoma Department of Agriculture). Therefore, it is now less necessary that flour be produced relatively near population centers. Consumers are also purchasing bread and flour products at home that are more convenient and have higher values, as opposed to purchasing flour and making flour-based products in the home. Wheat flour-based products of this nature include frozen foods that are heated or baked, breads, and dough that require only minimal preparation prior to consumption. Ready-to-eat cookies and crackers are also among the rapidly growing products (Putnam and Gerrior).

With all these divergent views regarding potential for wheat milling capacity expansion in Oklahoma supported by literature, the question then is 'does Oklahoma need to expand its capacity?' Several researchers have attempted to study one aspect of the state's wheat industry or the other. Schmitz, for example, attempted to determine the optimal wheat flow patterns for the state under different transportation arrangements. However, no effort has yet been devoted to determination of the optimal configuration of the entire wheat marketing industry. Industry planning and development, though, requires this kind of information.

Potential for increasing wheat milling in Oklahoma is evaluated from two perspectives. First, food processors' flour type preferences are contrasted with type of wheat produced in the state. In-depth flour market information was obtained by means of a survey. The survey provided data on magnitude of excess flour demand (by type) currently not met by Oklahoma millers. In the second phase of the analysis, replacing out-of-state flour sources with an expanded domestic flour milling industry is considered by means of mixed integer programming techniques.

The model aims at minimizing the total costs of wheat, flour and millfeed shipments, of constructing flour mills, and of processing the wheat at the mill. One of the major findings of the survey was that the hard-red winter wheat produced in the state was not compatible with food processors' preferences, who use mainly soft wheat-based flour. Thus, relaxing the state's soft-wheat production constraint constituted a major part of sensitivity analysis in the mathematical programming models.

Objectives

The general objective of this study is to determine if Oklahoma has potential to increase its wheat processing capacity. Specific objectives are to:

1. determine the quantity and quality characteristics of wheat flour needed by Oklahoma food processors and currently supplied by out-of-state firms;
2. determine the costs of building processing facilities that could potentially meet the apparent excess flour demand;
3. determine the optimal size and distribution of additional flour milling capacity required to meet Oklahoma's excess flour demand; and
4. determine conditions that would increase the probability of profitable wheat processing in Oklahoma.

Organization of the Study

This section presents an overview of the organization of the rest of the chapters in this study. Theoretical considerations underlying the analytical approach used in the study are outlined in Chapter II. Literature review on theoretical and empirical development of spatial equilibrium and plant cost analyses are presented in Chapter III. Data sources and the empirical models used in this study are specified in Chapter IV. A more complete presentation of the modeling logic, assumptions, and equation-by-equation description of the empirical model is also presented in Appendix A. Chapter V presents the findings of the study and their analyses. The study summary, conclusions, limitations and suggestions for future research are contained in Chapter VI.

CHAPTER II

CONCEPTUAL FRAMEWORK

In a perfectly competitive market environment, prices will differ by the costs of transfer among different levels of the marketing channel. These transfer costs constitute the value of form, place, time, and/or possession utilities created in the productive process of marketing (Kohls and Downey). Thus, in considering the optimal distribution of new flour milling capacity, all the costs associated with wheat and flour marketing (transportation, storage, processing, and transactions) must be taken into account, wherever possible.

Much of economic theory seeks to explain economic phenomena that are assumed to exist in a spaceless world. With many problems, this approach may be appropriate, but there also exist certain economic problems that require explicit consideration of the effects of space. Many of these situations exist in agriculture where production of commodities often is geographically distributed in patterns considerably different from the locations of final product consumption. Thus, one component of the farm-retail price spread for agricultural commodities, such as wheat, involves the transportation costs of moving the farm commodity to processing locations and distributing the consumer products to final demand locations.

Location of Economic Activity

The plant location problem has been most successfully analyzed by mathematical programming techniques, which provide a logically consistent method to evaluate alternative economic scenarios and industry structures. The optimal plant location is determined at the unique point that minimizes total transportation and processing costs by balancing the locational pulls exerted by raw material inputs and markets. Empirically, the optimal number, size and location of agricultural processing plants can be approached in two ways (French): continuous space and discrete space optimization. The continuous space formulation assumes that commodity production and marketing activities are dispersed in a continuous manner. A major difficulty with this approach, however, is that supply density typically is not uniform and supply areas are not regular and continuous in space (French). Moreover, there often are limited numbers of realistic choices of efficient locations, and plant cost functions may not be independent of these locations.

An alternative to the continuous space approach, the discrete case, is to group supply sources and market territories into finite numbers of point locations and to consider some predetermined set of feasible potential plant locations. French shows that the discrete case is a special case of the more general continuous case, in which production occurs at specific discrete points on the plane and assembly costs include only the costs of moving product from these points to the plant. Faminow broadly categorizes the commonly used agricultural plant location models into a) linear programming and transshipment models; b) Stollsteimer location models; and c) mixed integer models.

Mixed Integer Programming

One limitation of the transshipment and Stollsteimer models is that they ignore fixed charges associated with plant establishment and operation. The opening of a plant, however, will typically involve a considerable initial plant investment plus other fixed costs that are amortized over the life of the plant. Additional fixed costs associated with operating the plant may also be incurred. Failure to consider these fixed costs may lead to research results that are of limited use to policy makers or industry (Faminow). Thompson and Thore formally present total capacity installation costs as:

$$\gamma_j y_j + \delta_j \Delta X_j , \tag{2-1}$$

where γ_j is the fixed-charge portion of capacity costs (all costs not associated with scale of operation of the activity), δ_j is the slope of the linear portion of the capacity expansion cost function, and $y_j \in \{0,1\}, \forall\, j = 1, ..., n$ is a binary variable, equal to 0 if new capacity $\Delta X_j = 0$ and equal to 1 if $\Delta X_j > 0$. This cost schedule has a discontinuity at the origin (see also Figure 3.1 below). If no new capacity is added, the cost is zero. If any positive amount of new capacity is added, the entire fixed charge must be paid (as well as variable costs). A general fixed-charge facilities location problem may be expressed as:

$$\min_{x_{ij}, y_j} Z = \sum_i \sum_j c_{ij} X_{ij} + \sum_j F_j y_j , \tag{2-2}$$

subject to

$$\sum_i X_{ij} \geq D_j , \qquad \text{(demand requirements)} \tag{2-3}$$

$$\sum_j X_{ij} \leq S_i , \qquad \text{(supply constraints)} \tag{2-4}$$

$$\sum_i X_{ij} \leq \Delta X_j y_j , \qquad \text{(capacity constraints)} \tag{2-5}$$

$$X_{ij} \geq 0, \qquad \text{(non-negativity of shipments)} \qquad (2\text{-}6)$$

where c_{ij} is the cost of transporting a unit of the raw material from source i to plant j; X_{ij} is the quantity transported from source i to plant j; S_i is supply upper bound at source i; D_j is the commodity demand that has to be met at plant j; and F_j represents the fixed costs associated with plant construction and operation. Symbols y_j and ΔX_j represent, respectively, 0-1 binary variables and optimal capacity associated with plant location j (as described above).

This is a simplified version of the problem. Most applied formulations would be more complicated, with inclusion of processing, storage and final product distribution variables. However, the general form of the problem remains unchanged.

CHAPTER III

LITERATURE REVIEW

Literature on optimum number, size and location of processing plants is very vast. This chapter, though by no means comprehensive, attempts to highlight important aspects of the theoretical approaches to analyzing spatial economics. The review is divided into two parts. The first part presents the development and empirical applications and models of spatial equilibrium theory. Optimization of market areas with any of these models requires some knowledge of the costs associated with the various marketing functions, including processing. Therefore, the second and final part of the review presents the theory and applications of the various ways of estimating plant cost relationships, with special focus on the economic engineering approach.

Spatial Equilibrium Theory

Economic theory suggests that, due to arbitrage, prices should differ, in a competitive market, among locations by not more than the cost of transportation, among time periods by not more than the cost of storage, and among forms by not more than processing costs (Bressler and King). The theory of the perfect market suggests that spatial differences greater than the cost of transportation are evidence of market imperfections. Thus, for spatially separated markets to be in equilibrium,

$$P_j - P_i \leq T_{ij}, \tag{3-1}$$

where price in the j^{th} market, P_j, is greater than price in the i^{th} market, P_i, and T_{ij} is the unit transportation cost between the two markets. Thus, a market boundary between any two competing markets is the locus of points so situated that the site prices (market prices net of transfer costs) for shipments made to the competing markets are equal (Bressler and King).

Geographical price differences are explained by the theory of the location of production and by the concept of the perfect market. The selection of a starting point for a discourse on these theories is largely arbitrary. The beginning is basically immaterial since one cannot delve into a part without considering the whole (D'Souza).

Development of Location Theory

Based on the concept of specialization, Plato's "ideal state" asserts that output can be increased by specialization and that exchange and trade are integral to a society. Smith extended this concept but attributed the gains from specialization to regional differences in natural resources and technological development, leading to the concept of absolute advantage and, hence, providing an explanation of why two regions trade.

Failure of the concept of absolute advantage to identify the commodities to be produced later led Ricardo into developing the principle of comparative advantage. Ricardo argues that each region should specialize in the production of those commodities for which it has the greatest relative advantage or which it can produce most efficiently, and import those commodities for which it has the most relative disadvantage compared to other areas. In this context, a prudent industry regulator, like a manager of a private operation, strives to design a marketing system that would provide for efficient flow of raw materials from their source of production through stages of processing to their ultimate destinations.

Modeling of this problem and, hence, empirical application of the concept of comparative advantage was first attempted by von Thunen, who later came to be known as the father of location theory. Focusing on transportation costs and land rent, von Thunen's work attempted to determine commodities to be produced in any given location, given the demand for those commodities. He hypothesized that land rents and distances from farm to city were the only variable factors in determining the most profitable system of land use. Under these conditions, the pattern of land use would be described by a series of concentric rings, with commodities bulky in proportion to their value being produced nearer to the market or city. Though von Thunen did point out the importance of transportation in location analysis, his assumptions led to an oversimplification of the problem. For example, the possibility of locating processing plants in the producing areas was not considered.

Weber later modified this approach and is generally credited with the path-breaking work on location theory. Weber's analysis was concerned with the problem of locating a plant, given the spatial separation of raw materials and markets, and the nature of the product (weight losing, gaining, or neutral). His 'material index', estimated as the ratio of weight of raw material to weight of final product, helped determine if an industry was material oriented or market oriented. If the index is greater than unity, for example, processing plants should be located at the source of the raw material to take advantage of transportation economies. Weber also introduced the phenomena of "agglomeration" and "deglomeration" in his analysis of industrial location. In his analysis, the optimal plant location was determined by the unique point that minimizes total costs of transporting raw materials to the factory and finished products to the consuming center.

First application of location theories to neoclassical theory of the firm was done by Palander, who, by modifying some of the weaknesses of Weber's theory, gave a broader framework of the influence of transportation routes and transport mediums upon industrial location. Palander also introduced the concept of spatial competition in the analysis of market areas.

Losch presented a general equilibrium system containing interrelationships of all locations, with optimal economic areas in the shape of a hexagon. His work was the first to emphasize the influence of demand on locational analysis. He differentiated an "actual" location from a "rational" location, explaining that the two do not always coincide. Losch also argues that the question of the best location is far more dignified than determination of the actual location.

Ohlin was among the first to integrate trade and location theories. He based his work on the "mutual interdependence" theory of pricing, which simultaneously determines prices, markets, industrial location, spatial distribution of factors and commodities. Losch and Isard attempted to integrate Walsarian general equilibrium theory and location theory. Isard further developed the concept of transport inputs and the substitution approach to location theory. Samuelson formulated the spatial problem based on maximization of the sum of consumer and producer surpluses, less transportation costs, in spatially separated markets.

Several efforts have also been made to determine the optimal size and shape of market areas. The limited case of a linear market was discussed by Hotelling and Smithies in attempts to determine optimal location given spatial competition between sellers. Fetter formally stated a law of market areas between two competing regions as being a hyperbolic curve. This law was later appended by Hyson and Hyson as being more generally a hypercircle.

Efficient Organization within Marketing Areas

Research dealing with efficiency of marketing areas or marketing sub-industry organization has focused mainly on the determination of the optimum (or least-cost) number, size, and location of marketing facilities (French). Two model classes have emerged for this problem: one which treats space as continuous for purposes of defining optimal marketing areas for individual firms, and the other which specifies finite numbers of markets, locations, and raw material sources.

The continuous space formulation assumes uniform density of raw material supplies and/or spatial density of demand. The number of plants is approximated by dividing the total regional supply by the optimum (or minimum cost) plant volume/capacity. Optimal plant volume is determined at the point at which the sum of long run average cost and average assembly and/or distribution costs is minimized (French). Since space is continuous, the first-order condition holds at that point. Because circular supply areas would need to overlap to blanket the entire region, hexagonal or, in the case of square grid road systems, square areas would be most efficient.

Olson was the first to use this approach to determine optimum size and number of agricultural marketing plants, in a study of milk assembly. Williamson later elaborated the model into a more general spatial equilibrium framework for plant location, including both competitive and monopsonistic cases. He also showed how, under certain assumptions, the model can be applied to cross-section data to obtain statistical estimates of the relation of optimum plant size to supply density. Variants of the Olson and Williamson models have been applied to grain elevator size and location by Von Oppen and Hill, and Araji and Walsh, to livestock markets by Miller and Henning, to optimum milk plant size by Cobia and Babb, and Babb, to cotton ginning and warehousing by Wilmot and Cable, and to petroleum distrbution to farms by Haskell and Manuel.

Most recently, Mwanaumo, Masters, and Preckel used a spatial equilibrium model in the continuous space setting to analyze the effects of three agricultural marketing policy options in Zambia: complete control, partial liberalization, and fully competitive market. They argue that to capture the costs of interregional transport from farms to depots, markets must be modeled in continuous space, rather than using the traditional point-representation of the market pioneered by Samuelson and operationalized by Takayama and Judge. By representing space as a continuum, the authors were able to explicitly include in their model the farm-to-market transactions costs for all producers and to determine endogenously the farmer's decision whether to participate in the market as well as the direction and level of sales and transport.

The major difficulty of the continuous space approach, however, is that supply density typically is not uniform and supply areas are not regular and continuous in shape. Moreover, there often are limited numbers of realistic choices of efficient locations, and the plant cost functions may not be independent of these locations. Under these circumstances, the continuous model may give very poor approximations to realistically efficient size and location solutions (French).

An alternative formulation, the discrete case, groups supply sources and market territories into finite numbers of point locations and considers some predetermined set of feasible potential plant locations. As in the continuous case, the discrete approach also needs knowledge of transportation cost functions (or all point-to-point rates) and the long run processing or hauling cost function.

The Stollsteimer Model. One of the first models for solving this type of problem was developed by Stollsteimer. Stollsteimer applied the programming framework developed by Lefeber and Isard to determine the optimum number, size, and location of pear-packing plants in a fairly homogeneous pear-producing region.

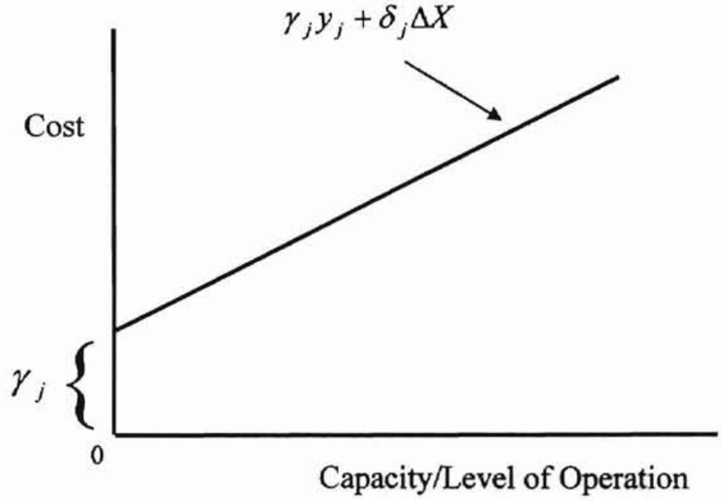
The ease or difficulty of solving the Stollsteimer problem is affected by the presence or absence of economies of scale, the form of processing cost function, the effects of location on plant cost, and the number of sources and potential plant locations to be considered. In his original application of the model, Stollsteimer introduced the strategic assumption, supported by empirical evidence, that the long-run total cost function for pear packing could be approximated by a linear equation with a positive intercept. The solution was then obtained by first computing the minimum assembly cost for each possible number of plants, expressing total processing plant cost as a linear function of plant numbers, adding the minimized assembly cost to the increasing processing cost function, and then determining the exact number of plants and volumes which minimize combined total costs.

The basic Stollsteimer model has been extended to encompass multiple product plants by Polopolous and to handle discontinuous plant cost functions by Chern and Polopolous. Ladd and Halvorson extended it further to include a procedure for testing the sensitivity of the model to changes in parameters.

The Transshipment Model. Although the Stollsteimer model may be used to determine optimum plant location, size, and numbers with respect to either assembly or distribution systems, it is not applicable to situations where both must be considered (French). One approach to this problem has been to use a transshipment model, which is a modification of the basic linear programming transportation model (King). The transshipment model classifies each production or consumption area as a possible shipment or transshipment point. Its first application to agricultural marketing, by King and Logan, used a "heuristic" technique to handle the problem of economies of scale in the study of livestock slaughter plant location.

Hurt and Tramel further developed the transshipment model to handle more than one level of processing, more than one plant at each level, and more than one final product. Leath and Martin extended the model to include inequality constraints, and Toft, Cassidy, and McCarthy developed a procedure for testing the sensitivity of the model to change in cost elements of the model. Miller and King further extended and compared several classes of programming models and computational procedures and applied the models to the determination of minimum cost locations for peanut plants.

Mixed Integer Programming. To build new productive capacity, many kinds of costs may be incurred, such as costs for research and development, and retraining of labor. However, the large cost items are those of buying and/or constructing new equipment, machinery, and plant, that is new real capital.



Source: Thompson and Thore, 1992.

Figure 3.1. Schedule depicting total costs of capacity expansion

Figure 3.1 shows a schedule relating installation costs to installed additional productive capacity ΔX_j (capacity to operate activity), with a discontinuity at the origin. The schedule also illustrates the presence of both the fixed-charge portion of capacity costs, γ_j, and variable costs, $\delta_j \Delta X_j$, where δ_j is the slope of the linear portion of capacity expansion cost function and y_j is a binary variable.

One major limitation of most of the models discussed above is that they ignore fixed charges, γ_j, associated with plant establishment and operation and this may lead to results that are limited in use to policy-makers or industry (Faminow). The fixed-charge facilities location problem has been considered widely in operations research literature. Although a number of algorithms and heuristics have been developed that technically could solve mixed-integer problems, they are limited to small problems. Until recently, most larger problems have been computationally unsolvable.

Geoffrion and Graves provided a breakthrough in the solvability of large mixed integer problems. They used the Benders Decomposition principle to decompose the complicated mixed integer problem into an integer master problem, which is relatively more difficult to solve, and a linear sub-problem. This modification made it possible to solve the linear sub-problem and use dual information to assist in the solution of the master problem. The procedure is followed iteratively with the addition of the dual information from the iteration (called a Benders' cut) acting as an additional bound.

Recent research on solution techniques for fixed charge facilities location problems has focused on use of efficient network codes. Barr, Glover, and Klingman report impressive computational experience from a code specifically designed to solve large-scale fixed charge problems with a relatively sparse transportation cost matrix. The code uses a special purpose branch and bound technique to solve mixed integer problems as a network where the integer variable is not included in the problem, but handled implicitly by the solution method. Helgason, Kennington, and Wong have developed a code that uses the underlying network structure of fixed charge problems and a heuristic that rounds continuous solutions to integer approximation.

To determine the impact of declining cotton production and new storage technology on optimal location of cotton ginning facilities in the Rio Grande Valley of

Texas and New Mexico, Fuller, Randolph, and Klingman developed a fixed charge intertemporal plant location model. They used a piecewise processing cost function to allow the use of overtime labor as an alternative to opening additional facilities during peak processing periods. Because the problem was too large for conventional mixed integer codes, it was reformulated into a network and solved using a special purpose primal network code that uses a minimum cost-flow network code.

Cleveland and Blakley used mixed integer programming techniques to determine the optimum number, size, and location of cotton gins and warehouses for three areas in the Oklahoma and Texas plain regions. The authors' aim was to find the least-cost organization of the industries in each study area by modeling all sectors within the marketing systems simultaneously. They also used partial equilibrium analysis to determine the direction and magnitude of structural changes in the industry in lieu of a dynamic modeling effort.

Sweeney and Tatham proposed a mixed integer programming model for the single-period location problem synthesized with a dynamic programming procedure to determine the optimal industry warehouse structure over multiple periods. They argue that previous studies neglected the interdependence in costs among warehouses for a single period and across periods. Mixed integer programming was used to obtain an optimal solution for each time period, following the heuristic solution procedure of Ballou. The authors then used dynamic programming on the least-cost static solutions to determine the minimum cost path through the T periods, taking into account the cost of moving from one warehouse configuration to another.

Kilmer, Spreen, and Tilley used the procedure of Sweeney and Tatham to determine long-run dynamic adjustments in the number, size, and location of fresh citrus packing houses in East Florida. In this study, a major departure from Sweeney and Tatham involved the inclusion of costs beyond period T. Kilmer, Spreen, and Tilley argue that failure to consider these costs biases the long-run dynamic results toward the initial plant configuration.

Other Models and Extensions. Capstick, Stennis, Lamkin, and Fondren formulated a model to analyze the long run potential of the Arkansas cotton industry and to determine if the existing gin capacity and locations were organized efficiently. Allowing five potential gin capacity sizes, this model also attempted to obtain a simultaneous solution for the optimum industry structure. A separable programming algorithm was used to simultaneously optimize the nonlinear cost functions for the 14-week and 32-week ginning seasons.

Ethridge, Roy, and Myers presented a departure from the previous studies by using the Markov chain analysis to describe and predict structural changes in the west Texas cotton industry. They incorporated both the stationary probability assumption of the traditional Markov chain technique and non-stationary transition probability assumption, using modifications developed by Hallberg. Changes in the size and cotton gin activity level over time were modeled, estimating transition probabilities of movement from one structural state to another. Size groups were categorized according to ginning capacity, while activity levels were specified as new entrants, dead gins, inactive gins, and active gins. Least squares regression was then used to determine the impact of the explanatory variables, allowing projections of the structure of the industry.

Estimation of Plant Cost Relationships

Several approaches have been used to estimate plant cost and efficiency relationships. French groups these approaches into three broad categories: 1) descriptive analysis of accounting data, which mainly involves combining point estimates of average costs into various classes for comparative purposes, 2) statistical analysis of accounting data, which attempts to estimate functional relationships by econometric methods, and 3) the economic-engineering approach, which "synthesizes" production and cost relationships from engineering data or other estimates of the components of the production function.

Descriptive analysis was the first method to be used in the study of marketing efficiency. Before 1940, for example, authors like Bartlett, and Dow applied this approach to the efficiency of the milk distributing sector. Some of the major factors that have made this approach popular are that it is relatively cheap, easy to understand, involves "real" costs, and may provide knowledge on levels of marketing costs and margins. However, because the record-keeping system and factors such as managerial efficiency, scale of operation and production methods are typically not standardized among plants, it is difficult to make the cost comparisons suggested by this approach. Descriptive analysis also offers no idea of the underlying functional relationships suggested by microeconomic theory.

Unlike descriptive analysis, statistical analysis attempts to develop quantitative estimates of production and cost functions or to test theoretical hypotheses about them. Dean, Dean and James, and Yntema were among the first researchers to apply statistical approaches to cost measurement in non-agricultural firms. The method developed was later extended and applied to a wide variety of production problems. Examples of applications to agricultural marketing include Beaton and McCoy, and Broadbent and Perkinson. Empirically, this approach uses data on total cost and output from sample firms for a single period or, rarely, over a number of years. However, attempts to derive theoretical cost curves from such data are jeopardized by possible distortions or biases owing to the character and treatment of the data or inappropriate specification and measurement in relation to the true model of cost behavior (French).

The Economic-Engineering Approach

An alternative to descriptive and statistical analysis of plant accounting data is to synthesize cost functions from engineering, biological, or other detailed specifications of input-output relationships. French describes the nature of economic-engineering analysis in terms of a series of procedural steps, which include: 1) system description, through visits and consultations of the firms of concern, 2) specification of alternative production techniques, 3) estimation of production systems, and 4) synthesis of cost functions.

A major limitation of the economic engineering technique is its high research cost as the amount of technical detail required to synthesize cost functions is often large. Moreover, as the size and complexity of the operation increases, it becomes more likely that the model builder will omit some aspect of cost (Black). The technique has also been criticized for the general lack of findings pertaining to diseconomies of scale. The Federal Reserve Commission also observes that although the engineering approach may handle technical aspects of production processes with considerable accuracy, estimates pertaining to management, sales, and service activities are apt to be very crude (French). In practice, however, the magnitude of distortion may be fairly small, particularly in view of the many other problems encountered with the statistical approach.

On balance, the economic engineering approach appears to offer more in terms of analytical power (though at a higher cost) than either the descriptive approach or the statistical approach (French). However, the optimal choice of method depends on the objectives of the study and the funds and data available. An amalgamation of all three approaches may be appropriate in some cases.

The economic engineering technique, as applied to agricultural marketing firms, was originated in the early 1940s by Bressler. It was later refined by the University of California (to which Bressler had transferred his services). The "California approach" so developed is described in detail in French, Sammet and Bressler.

Adam, Kenkel and Anderson used the economic engineering approach to determine the costs and benefits of cleaning wheat. In their analysis, the authors determined the scale or size of equipment by observing output levels of key pieces of equipment, and by the output level required by the hypothetical production problem being considered. Fixed costs, variable costs, and benefits were then estimated for each cleaning system at both the individual firm and aggregate market levels. Zugarramurdi, Parin and Lupin used economic engineering to study the microeconomics of the fish processing industry in developing countries.

CHAPTER IV

PROCEDURES AND DATA SOURCES

Survey of Oklahoma Commercial Food Processors

To accomplish Objective 1, a comprehensive survey of major Oklahoma flour users was conducted, under the auspices of the Oklahoma State University's Food and Agricultural Products Research and Technology Center (FAPC). The survey elicited specific information on the quantity of flour used annually, the locations of flour suppliers, and flour type and quality specifications for each product manufactured. In addition, each company was also asked to rate the importance of a list of characteristics that may affect their choice of flour suppliers.

Prior to mailing, the questionnaire was reviewed by the relevant wheat industry stakeholder organizations such as the FAPC and Oklahoma Department of Agriculture for content and question relevance. The changes suggested by these reviewers were then incorporated into the instrument. In addition, the instrument was also pre-tested with a few randomly selected food processors. Questionnaire pretest helps to determine whether the respondents would be able to perceive the questions correctly and hence answer them as expected. It was, thus, useful in fine-tuning the answer choices, making them more relevant to the study population. A copy of the final instrument is attached in Appendix C.

The Survey Data Collection Method

Warde identifies four generally accepted ways of collecting data in the context of sample survey methods. These include 1) personal interviews, which involve dispatching interviewers to collect data directly from every designated element of the sample; 2) telephone interviews, where designated respondents are contacted and asked questions on the telephone; 3) self-administered questionnaires, representing the collection of data through the respondent's completion of a document, which may be dispatched through the mail or by hand delivery; and 4) examination of available data, which involves collection of secondary data. Recent developments in interviewing methodology include computer assisted telephone interviewing (CATI) and computer assisted personal interviewing (CAPI).

In this study, survey data were collected by means of a questionnaire, administered by mail. Several factors were considered in making this choice of survey data collection method of which bias, cost and time were of importance. Thus, the final decision took into account most of the trade-offs of each method. For example, the self-administered surveys are relatively more effective in reducing, if not eradicating, interviewer bias as there is hardly any direct contact between the interviewer and the respondents. The telephone interview approach was used only as an additional non-respondent follow-up mechanism. Its use in the main survey was avoided for reasons of time and probable increased cost from repeated telephone calls.

The Sample Frame

The Oklahoma Department of Commerce conducts a business and industry survey every year in which an attempt is made to draw up, among other things, a directory of manufacturers and processors. The current study used, as a sample frame, the latest listing of entrepreneurs from the department's '1996 Business and Industry Survey'. By definition, a frame is a method of locating *every* element in the frame *uniquely* (Warde). The terms "every" and "uniquely" in the above definition are very cardinal to the validity of a sample frame. Violation of one or both of these terms leads to frame problems. There are four most commonly encountered frame problems in surveys: missing elements; duplicates; blanks or foreign elements; and clusters.

When compared with an independent listing, prepared by the Oklahoma Department of Agriculture through the "Oklahoma Company Survey", some food processors were found to have been missing from the initial frame (the missing element problem). To obtain a more complete frame, the two listings were combined through the process of concatenation. Further adjustments were later made to the frame after discovering that some listed food manufacturers were either no longer in business or had moved and could not be traced (the foreign element problem) by deleting such names. After all these adjustments, the final frame comprised forty-six (46) major food processors. The forty-six included all large bakers (over 10,000 cwt. annual flour use) and many small (less than 1,000 cwt. annual flour use), family-owned businesses. With such a small survey population, an attempt was made to survey the entire survey population (a census). A 41 percent response rate was realized in the study, following two mailings and about 300 minutes worth of follow-up telephone calls.

Simple descriptive methods were used to analyze the survey results. Specifically, techniques like 'averaging', 'aggregation', 'plotting', and 'graphing' were used for the purpose, with the help of Microsoft Excel. Non-response was analyzed at two levels: overall non-response and question-by-question (or item) non-response analyses. At both levels, the analysis proceeded by computing non-responses as a percentage of the survey sample size[1].

The Mathematical Programming Model

The plant location problem has been most successfully analyzed by mathematical programming techniques, which provide a logically consistent method for evaluating alternative economic scenarios and industry structure (Eshleman). Thus, to accomplish objectives 3 and 4, a wheat processing plant location model was developed to minimize total transportation, processing and mill construction costs associated with replacing flour imports with Oklahoma-milled flour. Wheat, flour, and mill feed shipments were used as choice variables in the model. Additionally, binary variables determined the viable locations for mill capacity addition or construction. The model is an economic engineering representation of the system of wheat production, wheat shipping and milling, flour shipping, millfeed shipping and flour usage in Oklahoma.

In addition to considering expansion of the existing Oklahoma flour mills, the model also considered other prospective locations based on the volume of local flour use.

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[1] In this case, the sample is also the survey population since no sampling was done.

Three mill sizes were considered for each prospective location. These sizes are 7000, 4900, and 3000 cwt. per day and were determined based on the daily capacities of the existing Oklahoma mills. The model allows existing mills to expand capacity or additional locations to build any one of these daily capacities as long as the total costs associated with milling and wheat, flour and millfeed flows are minimized.

Interstate trade was incorporated into the model by including out-of-state sources for each type of wheat and flour. External sources of flour (both soft and hard) were determined from survey responses. Production centers of the various wheat types, presented by Harwood, Leath, and Heid, represented out-of-state sources of the respective wheat types. To avoid subjecting the model to unnecessary active constraints with regard to commodity importation, the model was specified without upper bounds on wheat and flour shipments from external sources. This formulation is justified because there are several alternative sources, with very high wheat and flour production levels. Therefore, only price ratios are the major determinant of how much of each of these commodities should be imported.

The analytical technique used in this study is a mixed integer programming model designed to minimize the combined costs of delivering wheat to mills, milling flour, and shipping flour and by-products to end users. The model is of the mixed integer variety because additional mill construction and capacity were allowed for only three discrete mill daily capacities. All other variables in the model were assumed to be continuous. The objective function for the mathematical programming model is given as:

$$\begin{aligned}\text{Min } Z = &\sum_{i=1}^{75}\sum_{w=1}^{2}\sum_{j=1}^{8}\sum_{p=1}^{3}\beta_{ij}X_{iwjp} + \sum_{e=1}^{2}\sum_{w=1}^{2}\sum_{j=1}^{8}\sum_{p=1}^{3}\beta_{ej}X_{ewjp} + \sum_{j=1}^{8}\sum_{p=1}^{3}\sum_{f=1}^{2}\sum_{k=1}^{8}\beta_{jk}R_{jpfk} \\ &+ \sum_{e=1}^{2}\sum_{f=1}^{2}\sum_{k=1}^{8}\beta_{ek}R_{efk} + \sum_{e=1}^{2}\sum_{f=1}^{2}\sum_{k=1}^{8}\rho_{ef}R_{efk} + \sum_{j=1}^{8}\sum_{p=1}^{3}\sum_{f=1}^{2}\sum_{k=1}^{8}\delta_{jp}R_{jpfk} \\ &+ \sum_{j=1}^{8}\sum_{p=1}^{3}\sum_{m=1}^{10}\beta_{jm}V_{jpm} - \sum_{j=1}^{8}\sum_{p=1}^{3}\sum_{m=1}^{10}\rho_{m}V_{jpm} + \sum_{j=1}^{8}\sum_{p=1}^{3}FC_{jp}Y_{jp}.\end{aligned} \tag{4-1}$$

The objective function is minimized subject to the following constraints:

$$\sum_{j=1}^{8}\sum_{p=1}^{3}X_{iwjp} - S_{iw} \le 0, \qquad \text{(wheat supply constraints)} \tag{4-2}$$

$$\sum_{f=1}^{2}\sum_{k=1}^{8}R_{jpfk} - CAP_{jp}Y_{jp} \le 0, \qquad \text{(annual flour capacity at mill)} \tag{4-3}$$

$$\sum_{j=1}^{8}\sum_{p=1}^{3}R_{jpfk} + \sum_{e=1}^{2}R_{efk} - D_{fk} \ge 0, \qquad \text{(satisfy flour demands)} \tag{4-4}$$

$$\sum_{k=1}^{8}R_{jpfk} - \sum_{i=1}^{9}\tau_{wf}X_{iwjp} - \sum_{e=1}^{2}\tau_{wf}X_{ewjp} \le 0, \qquad \text{(wheat/flour balance at mill)} \tag{4-5}$$

$$\sum_{m=1}^{10}V_{jpm} - \sum_{i=1}^{75}\sum_{w=1}^{2}X_{iwjp}(1-\tau_{wf}) \le 0\,, \qquad \text{(millfeed supply constraints)} \tag{4-6}$$

$$\sum_{p=1}^{3}Y_{jp} \le 1, \qquad \text{(mill number upper bounds)} \tag{4-7}$$

$$X_{iwjp}, X_{ewjp}, R_{jpfk}, R_{efk}, V_{jpm} \ge 0. \qquad \text{(non-negativity conditions)} \tag{4-8}$$

The variables in the model are defined as:

Z = total shipment, processing and annual fixed costs,

X_{iwjp} = quantity of wheat type *w* shipped from source *i* to plant size *p* at location *j*,

X_{ewjp} = quantity of wheat type *w* shipped from out-of-state source *e* to plant size *p* at location *j*,

S_{iw} = quantity of wheat type *w* produced at source *i*,

R_{jpfk} = quantity of flour type *f* shipped from plant *j* of size *p* to market *k*,

R_{efk} = quantity of flour type *f* shipped from out-of-state source *e* to market *k*,

V_{jpm} = quantity of millfeeds shipped from flour size *p*, location *j*, to millfeed market *m*,

D_{fk} = total quantity of flour type *f* used at market *k*,

β_{ij} = unit transportation cost per *cwt.* from wheat source *i* to plant location *j*,

β_{ej} = unit transportation cost per *cwt.* from out-of-state wheat source *e* to plant location *j*,

β_{jk} = unit transportation cost per *cwt.* from plant location *j* to market *k*,

β_{ek} = unit transportation cost per *cwt.* from out-of-state flour source *e* to market *k*,

β_{jm} = unit transportation cost per *cwt.* from plant location *j* to millfeed market *m*,

ρ_{ef} = unit price per *cwt.* of flour type *f* at out-of-state source *e*,

ρ_{m} = average unit price of millfeeds,

δ_{jp} = unit processing variable costs per *cwt.* at plant size *p* location *j*,

Y_{jp} = binary variable for building plant size *p* at location *j*, equal to one if mill construction is viable at the location, equal to zero otherwise.

FC_{jp} = annual fixed costs associated with building and operating plant size *p* at location *j*,

τ_{wf} = wheat-to-flour transformation rate, and

CAP_{jp} = annual capacity of mill size *p* at location *j*.

Details about the modeling logic, assumptions, and full technical description of this formulation are provided in appendix A. Empirically, two versions of the above model were estimated. In Version I, wheat production in Oklahoma was restricted to the type and proportions of wheat currently grown in the state, in addition to imported wheat. In Version II, the model was allowed to ship either hard or soft wheat from each production region. Also in Version II, soft wheat proportion was permitted to vary for each county, with 100 percent as the upper bound. The output from Version II helps to determine if increased production of soft wheat would greatly change the model results.

GAMS codes (or the program) for solving the two model versions are presented in appendix B[2].

At the optimum, an estimate of the unit cost of flour to the end-users was obtained by dividing the objective value by the total volume of flour shipped. To get estimates of the savings (per cwt. of flour) associated with the optimal industry reorganization suggested by each of the model versions, the respective unit cost estimates were subtracted from the estimates of the base model. Base model cost estimates were obtained by running the model with current wheat production pattern (like version I) but with an extra constraint restraining it from constructing any flour mills.

Data Sources

To empirically apply the above mathematical programming model, it is important that data be made available for the various model components. Data requirements for the model includes: 1) volume of wheat produced at each possible supply point and the price of wheat at each supply point; 2) wheat shipping costs from supply points to prospective mill sites and wheat price at source; 3) milling costs and capacity at existing mills and at potential new mill locations; 4) wheat-to-flour transformation rates and by-product production; 5) wheat flour and by-product (millfeeds) shipping costs and price at market or f.o.b flour mill; and 6) quantity of flour and by-products needed at each possible demand point and estimates of unit flour production costs at mill.

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[2] GAMS stands for 'General Algebraic Modeling System', the name of the optimization software used in this study.

Flour mill costs and input-output data

Industry accounting data are often nonexistent, unreliable, or difficult to obtain (French). In such situations, the economic engineering approach becomes an alternative for estimating and comparing transportation, processing, and other costs associated with building and operating processing plants of different sizes. The economic engineering technique uses engineering coefficients for input-output relationships and applies relevant input costs and cost allocations to estimate total cost and revenue for the plants (Allen, Eidman and Kinsey).

One of the major limitations of the economic engineering approach is that it is very costly to implement empirically because of the technical detail needed. To reduce the costs of synthesizing cost functions, French suggests use of systematic tabulation of accumulated information on physical input-output relationships. Such data can then be used in other studies involving similar operations. Work presented in a bulletin edited by Pearson and Brooker represents one of the first coordinated efforts using this method. Sammet has also suggested a basis for evaluating the transferability of such microeconomic data over time.

Following this approach, the current study uses data in Flores's Mill Management Economic Model (MMEM) to estimate the mill construction and operating costs and the input-output relationships for the flour mills in the model. Thus, objective 2 was treated by means of the economic-engineering approach. Specifically, the data obtained from the MMEM include wheat-to-flour and wheat-to-millfeeds transformation rates, unit wheat flour processing costs, and flour mill fixed costs (including the fixed-charges). For details about mill construction and operating costs, see also Eustace, Niernberger and Ward. Because the MMEM was based on only one mill size (7000 cwt.), these data were adjusted to meet the requirements of the other two mill sizes used in the current study. The adjustment proceeded by first computing fixed costs per unit of flour, multiplying this by the mill capacity, and then multiplying the product by a factor representing size economies.

This study uses estimates from Eustace, Niernberger and Ward to estimate the gains in economies from small mill sizes to larger ones. The authors estimated that costs decline by 21 percent in going from the small to the medium-sized mill, by 30 percent in going from the small to the large mill size, and by 11 percent in going from medium to large mill size. To account for inflation and other effects of passage of time, cost data were updated to current prices using the United States gross domestic product (GDP) deflator, 1995 base year.

Wheat and Flour Production and Market Data

Data on volume of flour use and flour quality and type preferences were obtained through a survey of commercial food processing companies. Survey details and procedures are discussed above. An unpublished informal telephone survey of Oklahoma shippers provided latest wheat, flour and millfeeds transportation rates. Annual wheat production data published by Oklahoma Agricultural Statistics Service were used to estimate wheat supply bounds for each county. Because of year-to-year variability in wheat production levels, the data were averaged over the 1990-96 period[3].

A visual presentation of the model's data sources and flow relationships is presented in Figure 4.1. The figure shows that the central component of the modeling process in this study is the wheat processing plant location model, a mixed-integer mathematical programming formulation. Also shown in Figure 4.1 are inputs to the model: the Mill Management Economic Model (MMEM) from Kansas State University, results from the flour use survey, wheat production data by county from Oklahoma Agricultural Statistics, transportation costs from the telephone survey of shippers, flour and wheat price data from Milling and Baking News, wheat price data from Oklahoma Agricultural Statistics and millfeed prices from Oklahoma State University Department of Animal Science web site.

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[3] Oklahoma Department of Agriculture shows a drop in wheat production from 120,245,000 bushels in 1991 to 93,100,000 bushels in 1996.

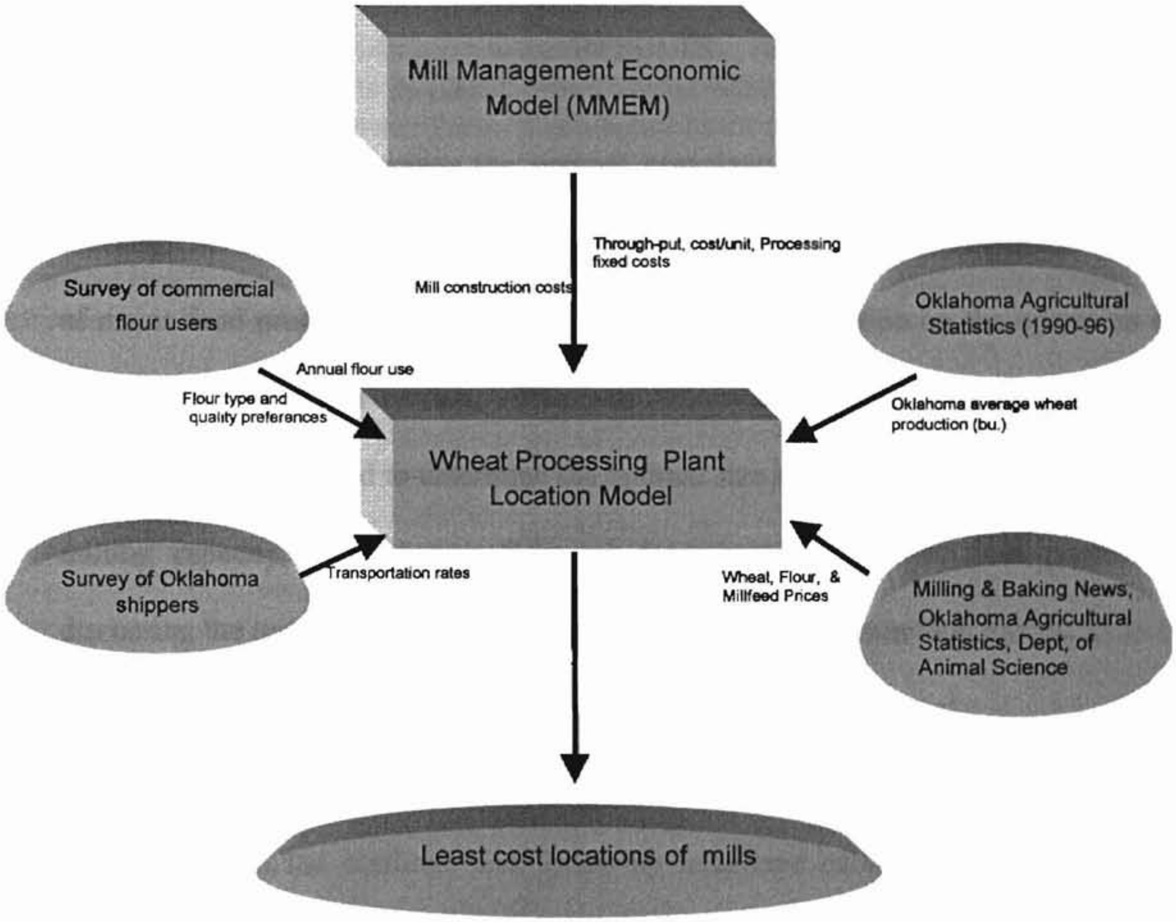


Figure 4.1. Flow chart for the wheat milling expansion potential project

CHAPTER V

RESULTS

This study determines the optimal organization of the Oklahoma wheat flour industry. As discussed above, the study was carried out in two phases. First, the survey of major food processors was conducted to provide information on the operation of the Oklahoma wheat flour market. This was followed by a mathematical programming model, which attempted to determine the optimal size and distribution of additional flour milling capacity. This chapter discusses the survey results and then proceeds into discussing the results of the mixed integer mathematical programming model.

Survey Results

Through the mailings and follow-up telephone calls, survey information was received from 19 of the 46 companies (41 percent response rate). Many non-responding small businesses stated in follow-up telephone calls that their operations were too small to warrant inclusion in this study. Item non-response rates varied from question to question but were highest in open-ended questions.

Flour Type

Although Oklahoma mainly produces hard-red winter wheat, most food processors produce soft-red winter wheat flour-based products. Cookies, for example, are the most commonly produced item, produced in one form or another by approximately 24 percent of the respondents (Figure 5.1). Note that the results presented in Figure 5.1 have no bearing on volume of flour use. They are based only on the relative frequency of each food item in the survey responses.

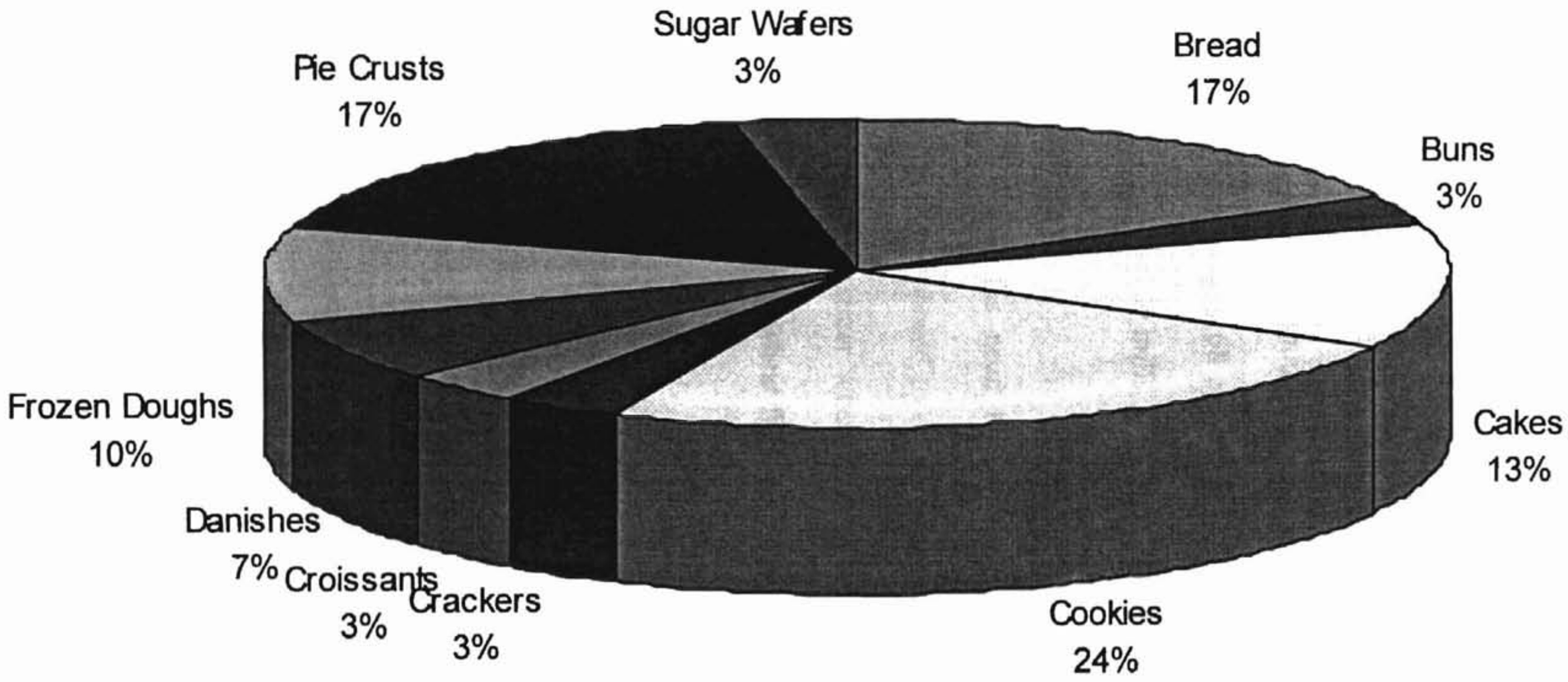


Figure 5.1. Relative importance of selected wheat flour products

In Figure 5.2, flour proportions by type of product are shown. The flour blends for major products show that there is divergence between the primary type of wheat produced in the state (HRW) and the predominantly soft wheat used by Oklahoma food processors (Figure 5.3).

Most of the commonly produced products have very high soft flour content. On aggregate, cookies from Oklahoma bakers are made almost solely of soft wheat flour. Quantitative data obtained from respondents also indicate that, out of about 2,830,000 *cwt.* total annual flour use, roughly 68 percent is soft wheat flour. Virtually all of this flour is purchased from out-of-state mills. Carthage, Missouri, was identified as a major source of soft wheat flour.

These results indicate the need to understand flour demand patterns when assessing milling potential as opposed to emphasizing current wheat production of the state. Production of hard-red winter wheat does not create a milling opportunity in Oklahoma. Use of soft-red winter wheat flour may, however, create a potential milling opportunity in the state.

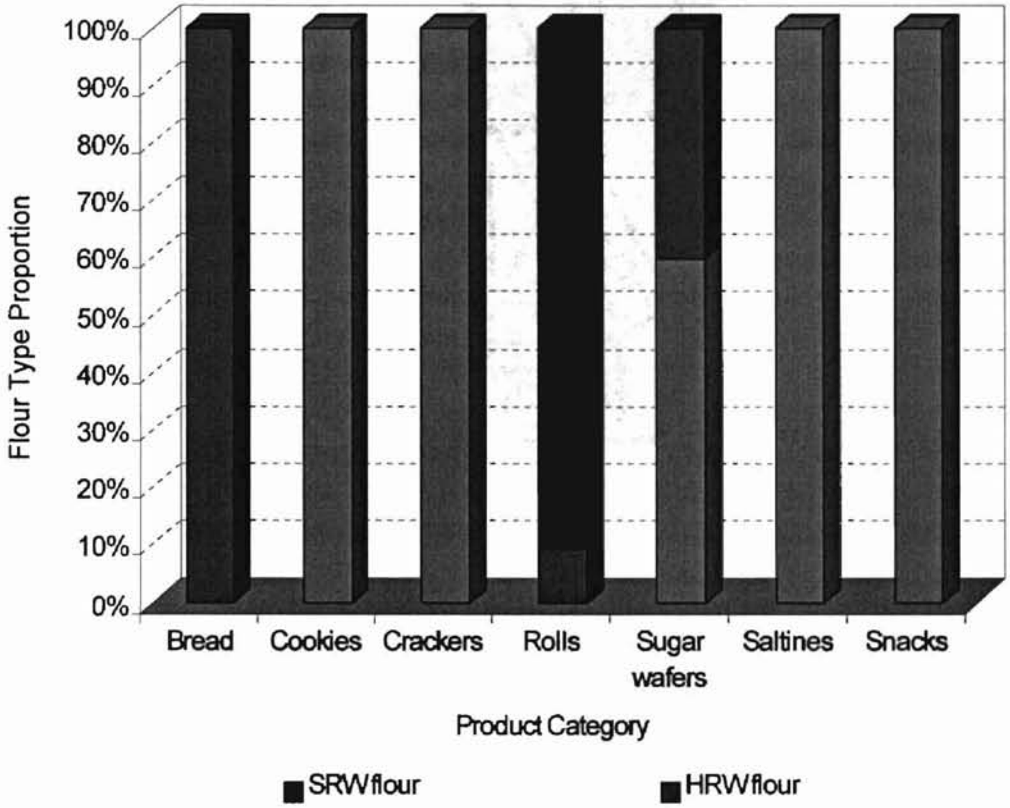
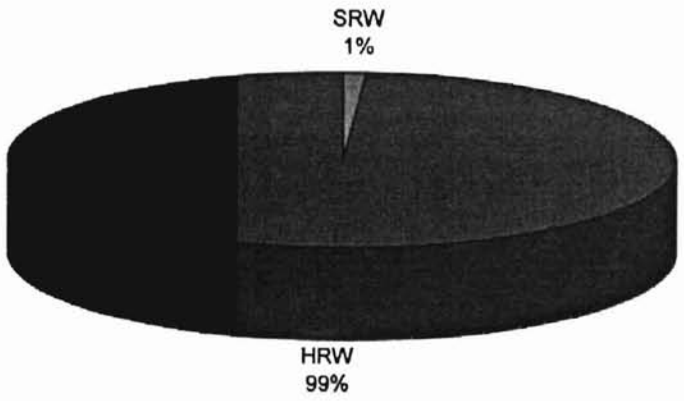


Figure 5.2. SRW and HRW wheat flour proportions for selected products

a) Oklahoma Wheat Production



b) Flour Use by Oklahoma Food Processors

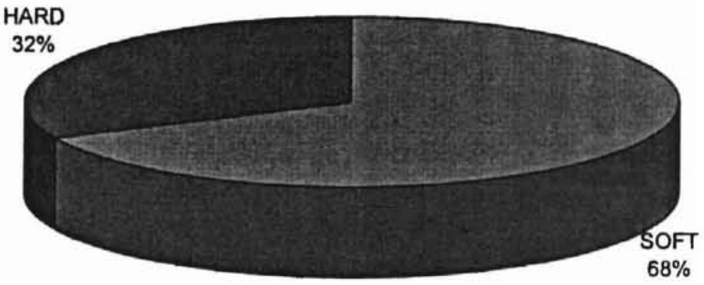


Figure 5.3. Comparison of wheat production and flour use by type

Flour Quality Characteristics

Respondents indicated that moisture, protein, and ash contents of flour were important. The acceptable ranges of these attributes were very small for individual firms, but across all respondents these factors ranged from 12.5-14 percent for moisture content, 8.5-14 percent for protein, and 0.48-1.60 percent for ash. Other factors, such as sieve analyses, gluten content, spread factors, and new-to-old crop wheat ratios, were also listed by different bakers.

As part of the survey, various service factors of flour suppliers were also given importance ratings by the survey respondents. Ratings were determined by way of a Likert scale, with 1 representing "Not Important," 6 representing "Very Important" and 2-5 representing varying levels of importance. "Consistency of flour quality" and "freshness of flour" were recognized by all respondents as being "Very Important." Likewise, "ability to produce desired quality" and "price level" were deemed especially important, with 87 percent and 75 percent of the respondents (respectively) valuing these attributes with a 6.

Respondents were also given the opportunity to make additional comments regarding factors important to their baking activities. Some of the comments received include:

1. A need for training of flour-based food manufacturers in new product development and marketing; and

2. A need to develop winter wheat varieties that give baking characteristics like hard red spring wheat: high protein levels which are generally used in frozen dough to give at least 120 days frozen shelf life.

These results also indicate the importance of understanding flour demand patterns when assessing milling potential as opposed to emphasizing only the wheat production side of the industry.

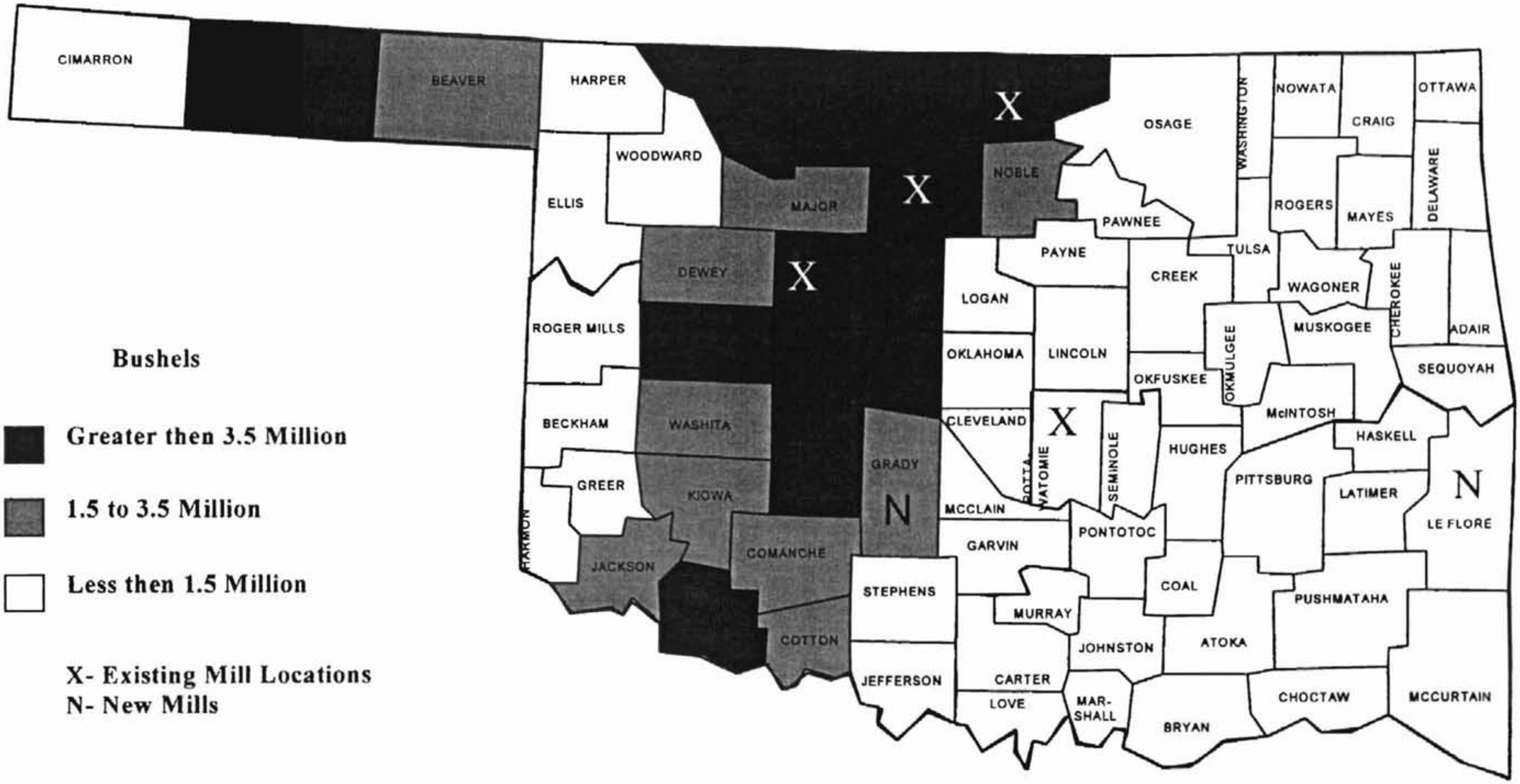


Figure 5.4 . Main wheat producing counties and flour mill distribution

Mixed Integer Programming Model Results

Figure 5.4 shows that, while wheat is grown in nearly every county of the state, the main wheat producing regions are in Western and North Central Oklahoma. The four existing flour mills are strategically placed in or close to these regions.

Version I results suggest that Oklahoma could expand current milling capacity by about 23 percent to serve the needs of existing flour users in Oklahoma. The best locations for any new wheat milling operations would be as shown in Figure 5.4. The new milling capacity would be best associated with flour needs of three large flour users in Oklahoma. Compared to the current situation, the results suggest that the cost of flour to end users could be reduced by $1.66 per cwt. of flour (holding wheat prices constant). Competitive pressures would be anticipated to cause the advantage to be shared by the miller, the wheat producer, and the flour end user. That is, competitive pressures would tend to cause both flour prices to fall and wheat prices to increase. Because the volume of wheat milled in Oklahoma would only change by 1.5 percent of total wheat production, little upward wheat price pressure would be created by the additional milling capacity. It is possible though that some producers who are willing to produce specific (soft wheat) varieties and qualities of wheat for a mill could receive a premium. This potential decrease in cost of flour to end-users is sufficient motivation for consideration of milling investment in Oklahoma.

The model suggests constructing two additional mills, one medium sized mill operating at 80 percent capacity and one small mill operating at full three-shift capacity. Experience suggests that the cost of transportation may be over estimated relative to the cost of mills, which seems to suggest that one mill operating with three shifts would be more realistic. When restricted to one location, the model suggested one large mill operating at near full capacity (98.6 percent) in Chickasha, still providing 100 percent of both HRW and SRW wheat flour to all demand points. While this may seem contradictory to the unrestricted Version I model, which suggested a larger mill in Poteau rather than in Chickasha, this suggestion is the result of the transportation differences and the flour demand points. The suggested Chickasha mill, while not close to the state's largest baker in Poteau, it is close to the state's second largest baker and several bakers in Central and South Central Oklahoma (Oklahoma City, Norman, Lawton, and Marietta). This one mill would provide hard, soft, and hard-and-soft flour blends to baking establishments in these two areas of the state, while also providing hard and soft wheat flour to Eastern and Northeastern Oklahoma. Additionally, placing a mill in Chickasha provides the transportation advantage of being near the larger HRW wheat-producing regions of the state.

The one-mill solution generated about 94 percent of the savings found in the two-mill solution. Because Oklahoma produces very little soft wheat, 2.6 million bushels of soft wheat needed by the end-users would have to be shipped into Oklahoma and then processed. Thus, while out-of-state flour purchases would cease, Oklahoma would need to ship in SRW wheat each year from out-of-state sources.

Because the volume of additional wheat milled in Version I is roughly 1.5 percent of the current total wheat production, one would anticipate little upward wheat price pressure created by the additional milling capacity. It is possible, though, that some producers willing to produce specific varieties and qualities of wheat for a mill could receive a premium. The potential decrease in the cost of flour to end-users should provide sufficient motivation for consideration of milling investment in Oklahoma.

Table 1 below summarizes the optimal flour shipments under the two different assumptions regarding soft-red winter wheat production in Oklahoma. Version I represents the solution with current wheat production pattern. Version II allows for flexibility in soft wheat produced in the state.

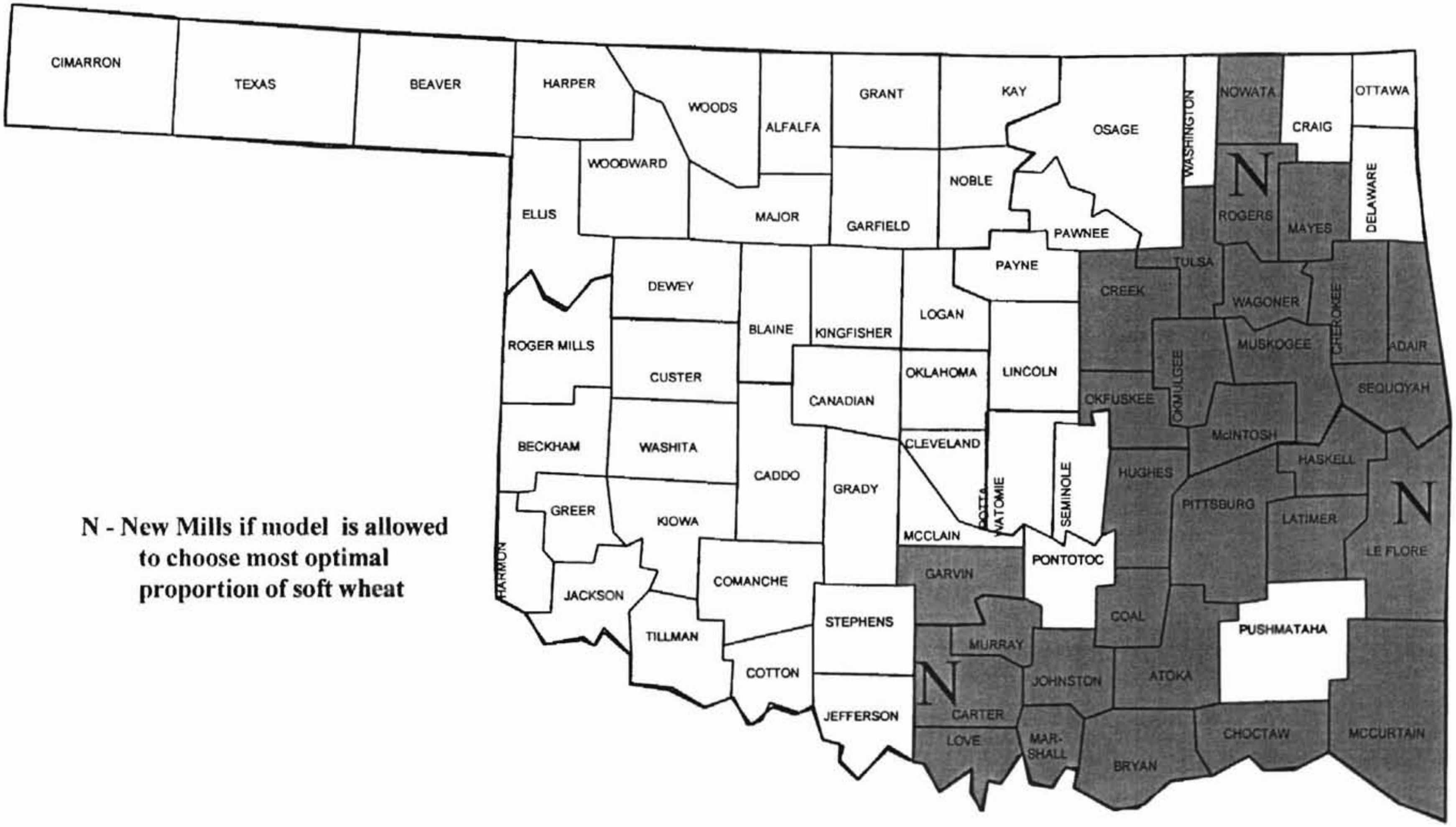
Table 1. Optimal Flour Mill Locations, Mill Sizes, and Flour Shipments (cwt., by wheat/flour type) to Demand Points

Demand Points	Optimal Mill Locations (Version I)				Optimal Mill Locations (Version II)					
	Poteau (Medium)		Chickasha (Small)		Catoosa (Small)		Poteau (Small)		Ardmore (Small)	
	HRW	SRW	HRW	SRW	HRW	SRW	HRW	SRW	HRW	SRW
Tulsa	18,327		141,240	344,128	159,567	344,128				
Oklahoma City				23,001						23,001
Lawton				62,400						62,400
Norman				2,500						2,500
Marietta			25,391	337,340					25,391	337,340
Vinita	50,000				50,000					
Poteau		1,150,000				214,000		936,000		
Total Flour Shipments	1,218,327		936,000		767,695		936,000		450,632	
Total Annual Capacity	1,528,800		936,000		936,000		936,000		936,000	
Percent Capacity Used	80%		100%		82%		100%		48%	

In Version II, the 2.6 million bushels of soft wheat needed to meet the flour needs of existing Oklahoma processors were "allowed" to be grown in Oklahoma. Under these circumstances, the results suggest that SRW wheat would replace HRW wheat in the Southeastern quadrant of Oklahoma. Shaded counties in Figure 5.5 are supposed to convert all their current wheat production into SRW wheat as determined by the model when allowed to choose the least-cost production/processing/shipping pattern (version II). Figure 5.5 also depicts the least-cost locations of the three small mills suggested by the Version II solution: Catoosa (Arkansas River port in Northeastern Oklahoma), Poteau (near the Oklahoma/Arkansas border), and Ardmore (South Central Oklahoma).

This solution is contingent on SRW wheat varieties having equivalent yields of both grain and pasture or that sufficient discounts or premiums are paid for SRW wheat. Some areas of Oklahoma currently have producers planting SRW wheat, but only for its superior winter forage production. Virtually none of those soft wheat acres are harvested for grain.

As is evident in Figure 5.6 below, the increase in the SRW wheat proportion resulting from the version II model is only about 2 percent of the state's total wheat production. Thus, on aggregate, the ultimate reorganization of the wheat production sector suggested by these results does not represent a significant departure from the existing structure.



N - New Mills if model is allowed to choose most optimal proportion of soft wheat

Figure 5.5. Counties that would increase proportion of soft red winter wheat to 100 percent

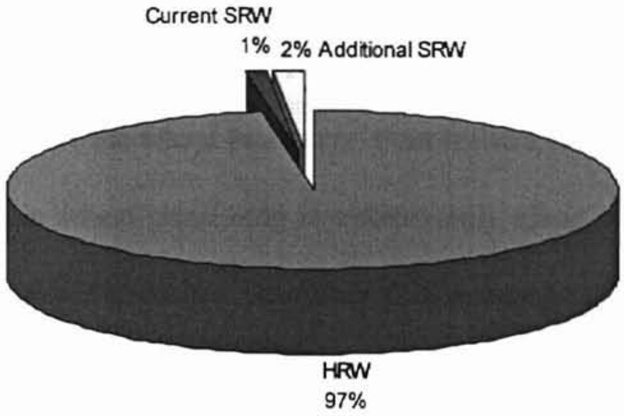


Figure 5.6. Increase in SRW wheat proportion suggested by model version II

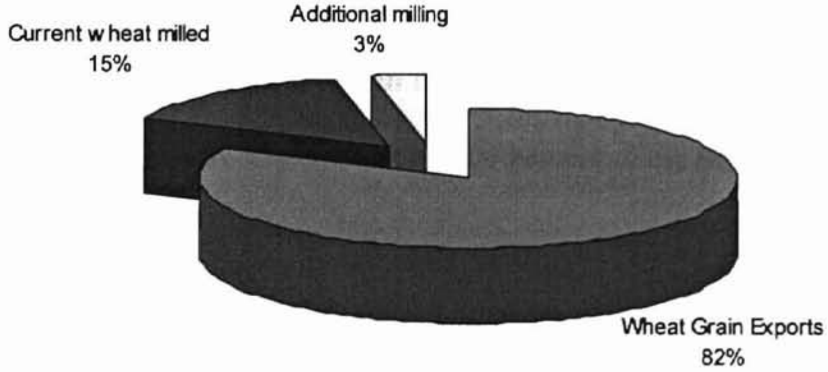


Figure 5.7. Additional wheat milling suggested by both model versions

Model version II suggests that, given additional milling capacity and SRW wheat production in Eastern Oklahoma, the cost of flour delivered to mills could be reduced by \$2.82/cwt. (holding wheat prices constant). Again, competitive pressures would cause the savings to be shared by the wheat producers, flour millers, and end users. However, the resultant increase in wheat processing represents only about 3 percent of a normal Oklahoma crop (Figure 5.7 above). Therefore, this reorganization is not expected to cause any considerable upward wheat price pressure. However, it is possible that wheat prices could be increased for producers with the quality and variety needed by the mills.

As with the Version I model, the Version II model was restricted to suggest one mill. Once again, the addition of one large mill to the state is probably more realistic than the addition of three small mills. As with the Verison I findings, the model suggested the addition of one large mill operating at 98.6 percent capacity. Also, the one-mill solution was slightly less cost efficient than the three-mill solution. However, the suggested location for the one large mill was in Catoosa, not Chickasha. The difference is due to the change in location advantages resulting from increased SRW wheat production in Eastern Oklahoma. As with the one-mill solution from Version I, this large mill would process both HRW and SRW wheat, meeting 100 percent of the flour needs at all demand points.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The survey of Oklahoma wheat flour users suggests that there is currently excess demand for flour in Oklahoma. Most Oklahoma food processors that are producing crackers and cookies require soft or soft-and-hard wheat flour blends for their recipes and are currently receiving soft flour from out-of-state suppliers.

The plant location model results suggest that there is potential to expand flour production in Oklahoma by as much as 23 percent of existing capacity if SRW wheat is produced in the state. Milling industry growth could come in the forms of expanded existing mills or new mills specifically designed to meet the needs of the end-users. Expanded milling becomes even more likely if growth continues in Oklahoma's value-added wheat products industry and if SRW wheat becomes more readily available from sources in Oklahoma. This identifies a need to refocus research and extension efforts toward supporting the emergence of the SRW wheat production sector. However, the impact of these changes on the entire wheat production sector is negligible, as is evident in Figure 5.7 above. Therefore, Oklahoma would still need to export the bulk (83 percent) of its wheat as grain.

The results also indicate that vertical market linkages are crucial in determining whether the suggested increase in milling capacity is feasible. Any individual or group considering a new milling venture will want to pursue quantity- and quality-based contracts with interested end-users prior to initiating investment in milling operations.

Limitations and Suggestions for Further Research

This study is not a feasibility study for a particular mill at a specific location, but it does provide a means for evaluating alternative mill locations given the flour needs of Oklahoma processors. The results reported in this study are based on the current flour demand in Oklahoma. Most certainly, should additional value-added flour-based products be produced in Oklahoma, opportunities for additional mills will increase. Likewise, should existing baking establishments reduce their needs for flour, milling expansion in Oklahoma would become less feasible. Changes in relative prices are also likely to influence the results.

The results also present several challenges for the marketing system. The ability of the grain marketing system to jointly handle SRW and HRW wheat has not been adequately tested. Segregation of SRW and HRW wheat would be difficult due to their similar exterior appearances, hence flour millers are often reluctant to buy wheat from areas where production is not uniform. This problem is reduced if one wheat variety is predominant in an area. In addition, it would be possible for various vertical linkage programs to allow contract production of alternative wheat varieties for specific flour milling uses. Unfortunately, while it is possible to contract for variety, it may be more difficult to contract for specifications within the variety. However, little research has been conducted in these areas. Further research and extension endeavors will be necessary to coordinate variety segregation activities with grain elevators and strengthen the vertical linkages of the wheat production and processing industries.

The decision to expand wheat milling may also be affected by factors such as the milling and other quality attributes of Oklahoma SRW wheat. Such information is currently unknown. Therefore, further research in that regard is necessary for the prospective investors in additional milling capacity. Risk of demand changes may also limit non-integrated expansion of the milling industry.

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APPENDICES

APPENDIX A

FULL DOCUMENTATION OF THE OKLAHOMA MIXED INTEGER PROGRAMMING FLOUR MILL LOCATION MODEL

The empirical problem in this formulation is to determine the optimal number, size, and location of flour milling facilities, given spatially dispersed and separated patterns of wheat supply and flour demand points. Optimal product flows of wheat, flour and millfeeds plus the level of processing in each facility were also determined. There are fixed costs associated with the establishment of milling facilities. This fixed charge represents the annual costs, independent of the actual volume, of opening a plant of given capacity for one year. Physical product flows from one region or location to another accrue a unit transportation cost. This problem falls into the class of problems known as fixed-charge facilities location models. Model decision variables are as listed below:

- Flows of wheat from supply areas to processing plants,
- Location of processing plants selected from *n* possible alternatives,
- Flows of wheat flour from processing plants to demand points,
- Flows of millfeeds from flour mills to millfeed markets, and
- Flows of wheat and flour from out-of-state sources.

The Oklahoma wheat industry is complex. To facilitate the analysis, simplifying assumptions were made in this study. This helped to reduce the size, scope, and intent of the model. Though restrictive, these assumptions are necessary in developing a workable economic model. Besides, since the real world is usually very complex, a theory or hypothesis need not be judged by the realism of its assumptions, but rather by the validity of its predictions when compared with experience (Friedman).

Model Assumptions

a) The dispersed distribution of wheat supply (HRW and SRW) may be separated into a finite number of regions in space and represented as such. In this case, Oklahoma counties and out-of-state sources are taken to be wheat sources. It is further assumed that each region may be indicated by a single point chosen to represent the center of wheat production activity (county seats or elevators for out-of-state sources). All intra-regional transfers are assumed costless;

b) The dispersed pattern of wheat flour use in the state may be separated into a finite number of regions in space and represented accordingly. This is somewhat in conformity with actual patterns of population and, hence, consumption density. Again, a single point is chosen to indicate demand in each region and all intra-regional transfers are assumed costless;

c) There are no barriers to trade. Thus, wheat, flour and millfeeds are free to flow among regions, without trade restrictions;

d) The model takes the view of the central planner, allocating resources so as to minimize the total industry costs. That is, the industry is taken to operate so as to minimize aggregate industry costs of transportation and processing while meeting final demand from available supplies;

e) Production levels and, hence, supply of wheat (HRW and SRW) in each supply region and the demand of flour are assumed to be known and fixed;

f) All the flour produced at each mill is shipped to demand points within the planning period (one year). That is, there is no storage of flour. This assumption is supported by Flores, who indicated, in the MMEM, that all flour produced was shipped to demand points;

g) All commodities (wheat, flour, and millfeeds by type) are assumed to be homogeneous. This conforms to perfect substitutability, assumed in the model, between regionally produced commodities (wheat, flour and millfeeds) and those imported from out-of-state and among commodities produced in different regions of the state;

h) Total processing costs at mill are a linear function of plant volume and have a positive intercept (fixed costs). In addition, wheat-to-flour and wheat-to-millfeed transformation rates are assumed constant and fixed at the mill; and

i) Total transportation costs include loading and receiving costs and are a linear function of volume, with a zero intercept.

Equation-by-Equation Description

The empirical mathematical model was designed to be consistent with the above assumptions. The model's major objective was to minimize aggregate industry costs subject to plant capacity, product flows, wheat supply, and soft- and hard- flour demand constraints. This sub-section provides a complete technical description of the model as formulated here.

The objective function, equation (4-1), reflects the costs of transporting wheat, flour and millfeeds, fixed costs of establishing processing facilities, and variable costs of milling flour. Millfeeds are assumed to be by-products in the milling process and their price (fob flour mill) is treated as a negative cost. The model uses four existing flour-processing locations and four new ones as prospective locations for milling capacity expansion. At each location, three possible mill sizes are considered. Fixed costs, FC_{jp}, are introduced through the use of the binary variable, Y_{jp}, where subscripts j and p are plant locations and mill sizes, respectively and $Y_{jp} \in \{0,1\}, \forall\, j = 1,...,8; p = 1,...,3$. If $Y_{jp} = 1$, the associated fixed cost of that facility is included in the total cost. If, however, $Y_{jp} = 0$, the facility is not selected and its fixed cost does not enter the total cost. The remainder of the objective function is similar to a conventional linear programming transportation problem.

Processing plant volumes and capacities are linked to the binary variable through the capacity constraints represented by equation (4-3). If $Y_{jp} = 1$, $CAP_{jp}Y_{jp} = CAP_{jp}$, the capacity upper bound. The total flour shipments from each plant, $\sum_{f}^{2}\sum_{k}^{8} R_{jpfk}$, which is equal to total volume produced is then bounded by $0 \le \sum_{f}^{2}\sum_{k}^{8} R_{jpfk} \le CAP_{jp}$. The optimal level of flour production is determined in the solution. If $Y_{jp} = 0$, then the expression $CAP_{jp}Y_{jp}$ also equals zero, by definition. Because $\sum_{f}^{2}\sum_{k}^{8} R_{jpfk}$ cannot assume negative values, it must also equal to zero.

Equation (4-7) represents upper bounds on the number of mills that can be built at each location. Because the model is provided with three possible mill sizes, the upper bound is one mill per location. If a particular mill size is too small, then a larger mill should be built as opposed to constructing several other small mills at the same location.

The largest mill size (7,000 *cwt.*) was strategically chosen such that it can satisfy all the excess flour demand, should the model find it optimal to build only one mill in the state. Considering the inconvenience of constructing several plants in the same location and the probable loss of scale economies, this constraint looks reasonable. Equation (4-2) imposes wheat supply constraints at each source. It tells the model that shipments of each type of wheat, *w*, from each wheat source, *i*, cannot exceed the quantity produced at that source.

Constraints represented by equation (4-4) are saying that all total flour shipments, from within Oklahoma and from out-of-state sources, should satisfy flour demand at each demand point. Total flour shipped from any mill cannot exceed total flour produced at that mill (wheat shipped to the mill from all sources multiplied by the wheat-to-flour transformation rate). This relationship, represented by equation (4-5), is reasonable in that its not possible to ship more flour than is actually produced, considering that the model assumes no flour storage (zero inventory) at the end of each planning year. Along the same line of argument, equation (4-6) says that total millfeed shipments from each mill cannot exceed total quantity of millfeed produced at that mill. The non-negativity condition, equation (4-8), constrains the model away from negative shipments, which do not make sense.

APPENDIX B

THE GAMS PROGRAM FOR THE FLOUR MILL LOCATION MODEL

Model Version I

```
$OFFUPPER OFFSYMXREF OFFSYMLIST OFFUELLIST OFFUELXREF

options limrow=0, limcol=0;
option optcr = 0.0000;
*option sysout = on;
option solprint=off;

SET
   I  Wheat Sources
      /PHBeaver, PNBoise, PHArnett, PHBuffalo, PHGuymon,
       WCSayre, WCWatonga, WCArapaho, WCTaloga, WCCheyenne,
       WCCordell, SWAnadarko, SWLawton, SWWalters, SWMangum,
       SWHollis, SWAltus, SWHobart, SWFrederic, NCCherokee,
       NCEnid, NCMedford, NCNewkirk, NCFairview, NCPerry,
       NCAlva, NCWoodward, CElReno, CNorman, CSapulpa,
       CChickasha, Ckingfishe, CChandler, CGuthrie, CPurcell,
       COkemah, Coklahoma, Cstillwate, CShawnee, CWewoka,
       SCAtoka, SCDurant, SCArdmore, SCCoalgate, SCPaulsV,
       SCWaurika, SCTishomin, SCMarietta, SCMadill, SCSulphur,
       SCAda, SCDuncan, NEinita, NEJay, NEPryor, NENowata,
       NEPawhuska, NEMiami, NEPawnee, NEClaremo, NETulsa,
       NEWagoner, NEBartlesv, ECStilwell, ECTahlequa, ECStigler,
       ECHoldenv, ECEufaula, ECMuskogee, ECOkmulgee, ECMcAlaste,
       ECSallisaw, SEHugo, SEPoteau, SEIdabel, SEWilburto/

   J  Plant Location
      /Enid, Shawnee, Blackwell, Okeene, Catoosa, Poteau, Ardmore,
      Chickasha/

   E  External Sources of wheat and Flour
      /Carthage, Wichita/

   K  Flour Markets
      /Tulsa, Oklahoma, Lawton,  Norman, Bethany, Marietta, Vinita,
      Poteaud/

   M  Millfeed Markets
      /MCheyenne, MCushing, MEnid, MOklahoma, MStillwate, MShawnee,
      MArdmore, MAda, MTulsa, MMuskogee/

   F  Flour Type
      /Hard, Soft/

   W  Wheat Type
      /HRW, SRW/

   P  Plant Size
      /SM, MD, LG/;

SCALAR SC   Wheat transportation cost per mile per cwt  /0.0023/ ;
```

```
SCALAR PC   Flour Processing Variable Cost per cwt /1.20/;

SCALAR FTR  Bu. of Wheat-to-cwt of Flour Trans. Rate    /0.45/;

SCALAR MTR  Bu. of Wheat-to-cwt of Millfeed Transf. Rate /0.15/;

SCALAR MP   Unit price per cwt of midds fob flourmill  /5.35/;

SCALAR XP   Unit price per bu of wheat  /3.57/;

PARAMETER S(I) County Wheat Production Estimates in bu.
    /PHBeaver      3924286
     PNBoise       3353571
     PHArnett      1767143
     PHBuffalo     2385429
     PHGuymon      8419714
     WCSayre       1801429
     WCWatonga     5495000
     WCArapaho     6037143
     WCTaloga      2631429
     WCCheyenne     841429
     WCCordell     5431429
     SWAnadarko    5707143
     SWLawton      2127143
     SWWalters     3560000
     SWMangum      1937857
     SWHollis      1112857
     SWAltus       4718571
     SWHobart      5630000
     SWFrederic    3771857
     NCCherokee    6925714
     NCEnid        9790000
     NCMedford     8925714
     NCNewkirk     7347857
     NCFairview    3936429
     NCPerry       4019429
     NCAlva        5625571
     NCWoodward    2019857
     CElReno       5452143
     CNorman        222429
     CSapulpa        47286
     CChickasha    2178571
     Ckingfishe    5705714
     CChandler      124143
     CGuthrie      1892857
     CPurcell       449857
     COkemah         94429
     Coklahoma      563286
     Cstillwate     632857
     CShawnee       214000
     CWewoka         47571
     SCAtoka         13429
     SCDurant       205000
```

```
     SCArdmore        79857
     SCCoalgate       18286
     SCPaulsV        293857
     SCWaurika      1070714
     SCTishomin       46857
     SCMarietta      193571
     SCMadill        103000
     SCSulphur        59143
     SCAda            20286
     SCDuncan        785286
     NEinita         543571
     NEJay           126429
     NEPryor         250000
     NENowata        297857
     NEPawhuska      727857
     NEMiami         930000
     NEPawnee        496429
     NEClaremo       267857
     NETulsa         192143
     NEWagoner       674286
     NEBartlesv      234286
     ECStilwell       24429
     ECTahlequa       12000
     ECStigler        86000
     ECHoldenv        76857
     ECEufaula        66857
     ECMuskogee      356571
     ECOkmulgee      117714
     ECMcAlaste       41429
     ECSallisaw      110714
     SEHugo           57857
     SEPoteau        124286
     SEIdabel        138000
     SEWilburto        9571 /;

PARAMETER MU(M) Annual millfeed use at midds market m in cwt
     /MCheyenne        26400
      MCushing        307200
      MEnid           268800
      MOklahoma       316800
      MStillwate      405600
      MShawnee        362400
      MArdmore        228000
      MAda            367200
      MTulsa           84000
      MMuskogee       415200/;


TABLE PROP(I, W) Proportions of wheat per county in percent
                   HRW      SRW
     PHBeaver     95.6        0
     PNBoise      95.6        0
     PHArnett     95.6        0
     PHBuffalo    95.6        0
```

PHGuymon	95.6	0
WCSayre	96.7	0.8
WCWatonga	96.7	0.8
WCArapaho	96.7	0.8
WCTaloga	96.7	0.8
WCCheyenne	96.7	0.8
WCCordell	96.7	0.8
SWAnadarko	94.6	2.2
SWLawton	94.6	2.2
SWWalters	94.6	2.2
SWMangum	94.6	2.2
SWHollis	94.6	2.2
SWAltus	94.6	2.2
SWHobart	94.6	2.2
SWFrederic	94.6	2.2
NCCherokee	95.6	0.3
NCEnid	95.6	0.3
NCMedford	95.6	0.3
NCNewkirk	95.6	0.3
NCFairview	95.6	0.3
NCPerry	95.6	0.3
NCAlva	95.6	0.3
NCWoodward	95.6	0.3
CElReno	91.2	0.4
CNorman	91.2	0.4
CSapulpa	91.2	0.4
CChickasha	91.2	0.4
Ckingfishe	91.2	0.4
CChandler	91.2	0.4
CGuthrie	91.2	0.4
CPurcell	91.2	0.4
COkemah	91.2	0.4
Coklahoma	91.2	0.4
Cstillwate	91.2	0.4
CShawnee	91.2	0.4
CWewoka	91.2	0.4
SCAtoka	77.2	6.1
SCDurant	77.2	6.1
SCArdmore	77.2	6.1
SCCoalgate	77.2	6.1
SCPaulsV	77.2	6.1
SCWaurika	77.2	6.1
SCTishomin	77.2	6.1
SCMarietta	77.2	6.1
SCMadill	77.2	6.1
SCSulphur	77.2	6.1
SCAda	77.2	6.1
SCDuncan	77.2	6.1
NEinita	87.6	4.1
NEJay	87.6	4.1
NEPryor	87.6	4.1
NENowata	87.6	4.1
NEPawhuska	87.6	4.1
NEMiami	87.6	4.1

```
     NEPawnee      87.6      4.1
     NEClaremo     87.6      4.1
     NETulsa       87.6      4.1
     NEWagoner     87.6      4.1
     NEBartlesv    87.6      4.1
     ECStilwell    64.9     10.3
     ECTahlequa    64.9     10.3
     ECStigler     64.9     10.3
     ECHoldenv     64.9     10.3
     ECEufaula     64.9     10.3
     ECMuskogee    64.9     10.3
     ECOkmulgee    64.9     10.3
     ECMcAlaste    64.9     10.3
     ECSallisaw    64.9     10.3
     SEHugo        15.5     58.9
     SEPoteau      15.5     58.9
     SEIdabel      15.5     58.9
     SEWilburto    15.5     58.9   ;

TABLE PP(E,F)  Price of flour at out-of-state source proxies in USD per
cwt
                    HARD    SOFT
     CARTHAGE              10.16
     WICHITA        9.47          ;

TABLE CAP(J,P) Annual Flour Capacity per Plant in cwt
              SM      MD      LG
    Enid      936000 1528800 2184000
    Shawnee   936000 1528800 2184000
    Blackwell 936000 1528800 2184000
    Okeene    936000 1528800 2184000
    Catoosa   936000 1528800 2184000
    Poteau    936000 1528800 2184000
    Ardmore   936000 1528800 2184000
    Chickasha 936000 1528800 2184000;

TABLE FC(J,P) Annual Costs of Building and Operating Plant J
              SM      MD      LG
    Enid      168480  244608  305760
    Shawnee   168480  244608  305760
    Blackwell 168480  244608  305760
    Okeene    168480  244608  305760
    Catoosa   168480  244608  305760
    Poteau    168480  244608  305760
    Ardmore   168480  244608  305760
    Chickasha 168480  244608  305760;

TABLE D(K,F) Annual Flour Demand at market k
               Hard      Soft
    Tulsa      159567    344128
    Oklahoma        0     23001
    Lawton          0     62400
    Norman          0      2500
    Bethany         0         0
```

```
    Marietta    25391     337340
    Vinita      50000          0
    Poteaud         0    1150000 ;

TABLE A(I,J) Distance from wheat source i to plant location j

                 Enid   Shawnee   Blackwell    Okeene
     PHBeaver     172       258         210           157
     PNBoise      275       411         327           260
     PHArnett     121       189         184            88
     PHBuffalo    122       208         151           107
     PHGuymon     213       299         265           198
     WCSayre      167       163         227           128
     WCWatonga     67       102         128            23
     WCArapaho    128       124         188            66
     WCTaloga      81       156         144            48
     WCCheyenne   187       183         247           148
     WCCordell    138       134         198            99
     SWAnadarko   115        93         161            85
     SWLawton     145       118         186           126
     SWWalters    168       141         209           149
     SWMangum     201       197         261           162
     SWHollis     221       205         273           182
     SWAltus      195       171         239           156
     SWHobart     160       156         220           121
     SWFrederic   194       167         235           165
     NCCherokee    53       185          75            53
     NCEnid         0       131          63            42
     NCMedford     35       152          26            76
     NCNewkirk     82       114          18           124
     NCFairview    41       134         104            20
     NCPerry       40        95          41            69
     NCAlva        73       205          95            71
     NCWoodward    87       173         150            72
     CElReno       64        62         126            65
     CNorman      118        50         119           110
     CSapulpa     118        83         121           183
     CChickasha   100        74         142            99
     Ckingfishe    39        87         100            42
     CChandler    120        29         121           134
     CGuthrie      69        65          70            70
     CPurcell     131        63         132           123
     COkemah      167        42         168           161
     Coklahoma     98        35          99            90
     Cstillwate    65        59          68            72
     CShawnee     131         0         132           125
     CWewoka      161        32         162           155
     SCAtoka      231       102         232           225
     SCDurant     244       127         245           236
     SCArdmore    196       128         197           188
     SCCoalgate   217        88         218           211
     SCPaulsV     156        57         157           148
     SCWaurika    166       139         207           165
```

SCTishomin	225	90	266	217
SCMarietta	211	143	212	203
SCMadill	217	100	218	209
SCSulphur	183	61	184	175
SCAda	180	51	181	174
SCDuncan	140	113	181	139
NEinita	178	156	181	220
NEJay	204	182	207	246
NEPryor	157	135	160	199
NENowata	168	148	110	210
NEPawhuska	106	128	62	148
NEMiami	203	181	206	245
NEPawnee	64	87	67	106
NEClaremo	144	122	147	186
NETulsa	115	95	118	157
NEWagoner	155	124	158	197
NEBartlesv	132	140	88	174
ECStilwell	213	159	216	278
ECTahlequa	188	136	191	230
ECStigler	207	121	210	240
ECHoldenv	167	38	168	161
ECEufaula	198	98	201	217
ECMuskogee	164	109	167	197
ECOkmulgee	155	73	158	192
ECMcAlaste	167	99	225	218
ECSallisaw	210	130	213	249
SEHugo	292	167	293	286
SEPoteau	243	163	246	282
SEIdabel	339	214	340	333
SEWilburto	257	132	258	251

+	Catoosa	Poteau	Ardmore	Chickasha
PHBeaver	303	415	321	232
PNBoise	495	568	474	385
PHArnett	273	346	252	163
PHBuffalo	253	365	271	182
PHGuymon	344	456	362	273
WCSayre	247	320	226	137
WCWatonga	186	259	165	76
WCArapaho	208	281	187	98
WCTaloga	240	313	219	130
WCCheyenne	267	340	246	157
WCCordell	218	291	197	76
SWAnadarko	181	250	114	19
SWLawton	206	275	115	45
SWWalters	229	298	86	68
SWMangum	281	354	196	124
SWHollis	293	362	204	132
SWAltus	259	328	170	98
SWHobart	240	313	219	77
SWFrederic	255	324	127	94
NCCherokee	185	297	250	152
NCEnid	131	243	196	100
NCMedford	152	264	217	162

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NCNewkirk    121       233      216       161
NCFairview   172       284      197       108
NCPerry       95       207      160       105
NCAlva       205       317      270       172
NCWoodward   218       330      236       147
CElReno      146       219      125        36
CNorman      139       207       83        34
CSapulpa      28       138      191       136
CChickasha   162       231       95         0
Ckingfishe   171       244      150        61
CChandler     77       187      142        87
CGuthrie     129       222      130        75
CPurcell     152       220       64        33
COkemah       77       123      124       110
Coklahoma    119       192       98        43
Cstillwate    87       199      163       108
CShawnee     109       163      128        74
CWewoka      113       150       95       104
SCAtoka      147       109       79       128
SCDurant     179       141       48       143
SCArdmore    217       188        0        95
SCCoalgate   147       109       79       114
SCPaulsV     177       245       46        55
SCWaurika    227       296       52        66
SCTishomin   171       149       35       124
SCMarietta   232       184       17       110
SCMadill     185       167       21       116
SCSulphur    164       169       33        82
SCAda        132       134       62        82
SCDuncan     201       270       76        40
NEinita       51       147      264       209
NEJay         77       125      290       235
NEPryor       30       121      243       188
NENowata      42       168      256       201
NEPawhuska    66       181      240       185
NEMiami       76       172      289       234
NEPawnee      72       184      188       133
NEClaremo     11       142      230       175
NETulsa       16       128      203       148
NEWagoner     41        97      239       184
NEBartlesv    55       170      248       193
ECStilwell    99        66      241       227
ECTahlequa    74        80      218       204
ECStigler     93        41      176       189
ECHoldenv     99       122      101       110
ECEufaula     84        91      153       166
ECMuskogee    50        83      191       177
ECOkmulgee    52       117      155       141
ECMcAlaste   113        75      126       167
ECSallisaw    96        37      212       198
SEHugo       173       120      103       235
SEPoteau     129         0      188       231
SEIdabel     220       103      150       282
SEWilburto   143        42      146       200;
```

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TABLE C(J,K) Distance from plant j to market k

               Tulsa  Oklahoma  Lawton  Norman Bethany Marietta
   Enid         115       98      145     118     102     211
   Shawnee       95       35      118      50      44     143
   Blackwell    118       99      186     119     103     212
   Okeene       157       90      126     110      84     203
   Catoosa       16      119      206     139     123     232
   Poteau       128      192      275     207     201     184
   Ardmore      203       98      115      83     107      17
   Chickasha    148       43       45      34      44     110

   +           Vinita  Poteaud
   Enid          178     243
   Shawnee       156     163
   Blackwell     181     246
   Okeene        220     282
   Catoosa        51     129
   Poteau        147       0
   Ardmore       264     188
   Chickasha     209     231     ;

TABLE B(E,J) Distance from External wheat source es to plant location j

               Enid  Shawnee Blackwell Okeene

   CARTHAGE    244     222     245       286
   WICHITA     121     190      62       163

   +           Catoosa  Poteau Ardmore
   CARTHAGE     117       190    330
   WICHITA      190       302    255   ;


TABLE H(E,K) Distance from external source es to market k

               Tulsa  Oklahoma  Lawton  Norman Bethany Marietta
   CARTHAGE     129      232      319     252     236     345
   WICHITA      174      157      244     117     161     270

   +           Vinita  Poteaud
   CARTHAGE       68     190
   WICHITA       237     302   ;

TABLE MD(M,J) Distance from millfeed market m to plant location j
                Enid Shawnee Blackwell  Okeene
     MCheyenne   187   183     247        148
     MCushing     82    63      83         98
     MEnid         0   131      63         42
     MOklahoma    98    35      99         90
     MStillwate   65    59      68         72
     MShawnee    131     0     132        125
     MArdmore    196   128     197        188
```

```
     MAda         180     51       181           174
     MTulsa       115     95       118           157
     MMuskogee    164    109       167           197

     +            Catoosa Poteau  Ardmore  Chickasha
     MCheyenne      267     340       246       157
     MCushing        79     175       166       111
     MEnid          131     243       196       100
     MOklahoma      119     192        98        43
     MStillwate      87     199       163       108
     MShawnee       109     163       128        74
     MArdmore       217     188         0        95
     MAda           132     134        62        82
     MTulsa          16     128       203       148
     MMuskogee       50      83       191       177       ;

VARIABLES
  X(I,W,J,P)     Quantity of wheat type w shipped from source i to plant j
  R(J,P,F,K)     Quantity of flour type f shipped from plant j of size p
                 to market k
  BYX(E,W,J,P)   Quantity of wheat type w shipped from out-of-state to
                 plant p at j
   BYF(E,F,K)    Quantity of flour type f shipped from out-of-state to
                 market k
   V(J,P,M)      Quantity of midds shipped from plant size p location j to
                 market m
   Z             'Total shipment, processing and annual fixed costs'
   Y(J,P)        Plant Building Activities
   PR(I)         Optimal proportion of SRW at source i
*  NM(J,P)       Number of mills of size p at plant location j;

POSITIVE VARIABLES X, R, BYX, BYF, V, NM, PR;
BINARY VARIABLE Y;

EQUATIONS
   COST           Objective Function
   FPROC(J,P)     Observe flour supply limit at plant j size p
   HFDEM(K)       Satisfy demand for hard flour at market k
   SFDEM(K)       Satisfy demand for soft flour at market k
   HWHTBL(J,P)    'HRW/Hard Flour Balance at mill'
   SWHTBL(J,P)    'SRW/Soft Flour Balance at mill'
   NOM(J)         Total number of mills at plant location j
   MIDBL(J,P)     Midds balance at each mill p and location j
   MID(M)         Balance of midds shipments at each midd market m
   SRWHT(I)       SRW wheat shipped from each source
   HRWHT(I)       HRW wheat shipped from each source
   PROPORT(I)     SRW proportion constraint
   OWHEAT(W)      Wheat from within Oklahoma (bu.)
   EWHEAT(W)      Total wheat from out-of-state sources (bu.)
   OFLOUR(F)      Flour produced by new capacity (cwt)
   EFLOUR(F)      Flour from out-of-state sources (cwt)
   PERCAP(J,P)    Percent of capacity used;
COST..        Z =E= SUM((I,W,J,P), X(I,W,J,P)*A(I,J)*(SC*0.6))
                + SUM((I,W,J,P), X(I,W,J,P)*XP)
```

```
                + SUM((J,P,F,K), R(J,P,F,K)*C(J,K)*(SC*1.25))
                + SUM((E,W,J,P), BYX(E,W,J,P)*B(E,J)*(SC*0.6))
                + SUM((E,W,J,P), BYX(E,W,J,P)*XP)
                + SUM((E,F,K), BYF(E,F,K)*H(E,K)*(SC*1.25))
                + SUM((E,F,K), BYF(E,F,K)*PP(E,F))
                + SUM((J,P,F,K), R(J,P,F,K)*PC)
                + SUM((J,P,M), V(J,P,M)*MD(M,J)*SC)
                + SUM((J,P), FC(J,P)*Y(J,P))
                - SUM((J,P,M), V(J,P,M)*MP) ;

SRWHT(I)..      SUM((J,P), X(I,"SRW",J,P)) - (S(I)*PR(I)) =E= 0;
HRWHT(I)..      SUM((J,P), X(I,"HRW",J,P)) - (S(I)*(1-PR(I))) =L= 0;
PROPORT(I)..    PR(I) - (0.01*PROP(I,"SRW")) =L= 0;
FPROC(J,P)..    SUM((F,K), R(J,P,F,K)) - CAP(J,P)*Y(J,P) =L= 0;
HFDEM(K)..      SUM((J,P), R(J,P,"HARD",K)) + BYF("WICHITA","HARD",K)
                      - D(K,"HARD") =G= 0;
SFDEM(K)..      SUM((J,P), R(J,P,"SOFT",K)) + BYF("CARTHAGE","SOFT",K)
                      - D(K,"SOFT")=G= 0;
HWHTBL(J,P)..   SUM(K, R(J,P,"HARD",K)) - (SUM(I, X(I,"HRW",J,P)*FTR)
                      + (BYX("WICHITA","HRW",J,P)*FTR)) =L= 0;
SWHTBL(J,P)..   SUM(K, R(J,P,"SOFT",K)) - (SUM(I, X(I,"SRW",J,P)*FTR)
                      + (BYX("CARTHAGE","SRW",J,P)*FTR)) =L= 0;
MIDBL(J,P)..    SUM(M, V(J,P,M)) - SUM((I,W), X(I,W,J,P)*MTR) =L= 0;
MID(M)..        SUM((J,P), V(J,P,M)) - MU(M) =L= 0;
NOM(J)..        SUM(P, Y(J,P)) =L= 1;
OWHEAT(W)..     SUM((I,J,P), X(I,W,J,P))=G=0;
EWHEAT(W)..     SUM((E,J,P), BYX(E,W,J,P))=G=0;
OFLOUR(F)..     SUM((J,P,K), R(J,P,F,K))=G=0;
EFLOUR(F)..     SUM((E,K), BYF(E,F,K))=G=0;
PERCAP(J,P)..   SUM((F,K), R(J,P,F,K)/CAP(J,P))*100=G=0;

Y.L("POTEAU","MD") = 1;
Y.L(J,P) = 1;
MODEL WHEAT /ALL/ ;

SOLVE WHEAT MINIMIZING Z USING MIP;

DISPLAY X.L;
*DISPLAY TOTWHT.L;
*DISPLAY TOTFLOUR.L;
DISPLAY R.L;
DISPLAY BYX.L;
DISPLAY BYF.L;
DISPLAY V.L;
DISPLAY PR.L;
DISPLAY NOM.L;
DISPLAY Y.L;
DISPLAY OWHEAT.L;
DISPLAY EWHEAT.L;
DISPLAY OFLOUR.L;
DISPLAY EFLOUR.L;
DISPLAY PERCAP.L;
```

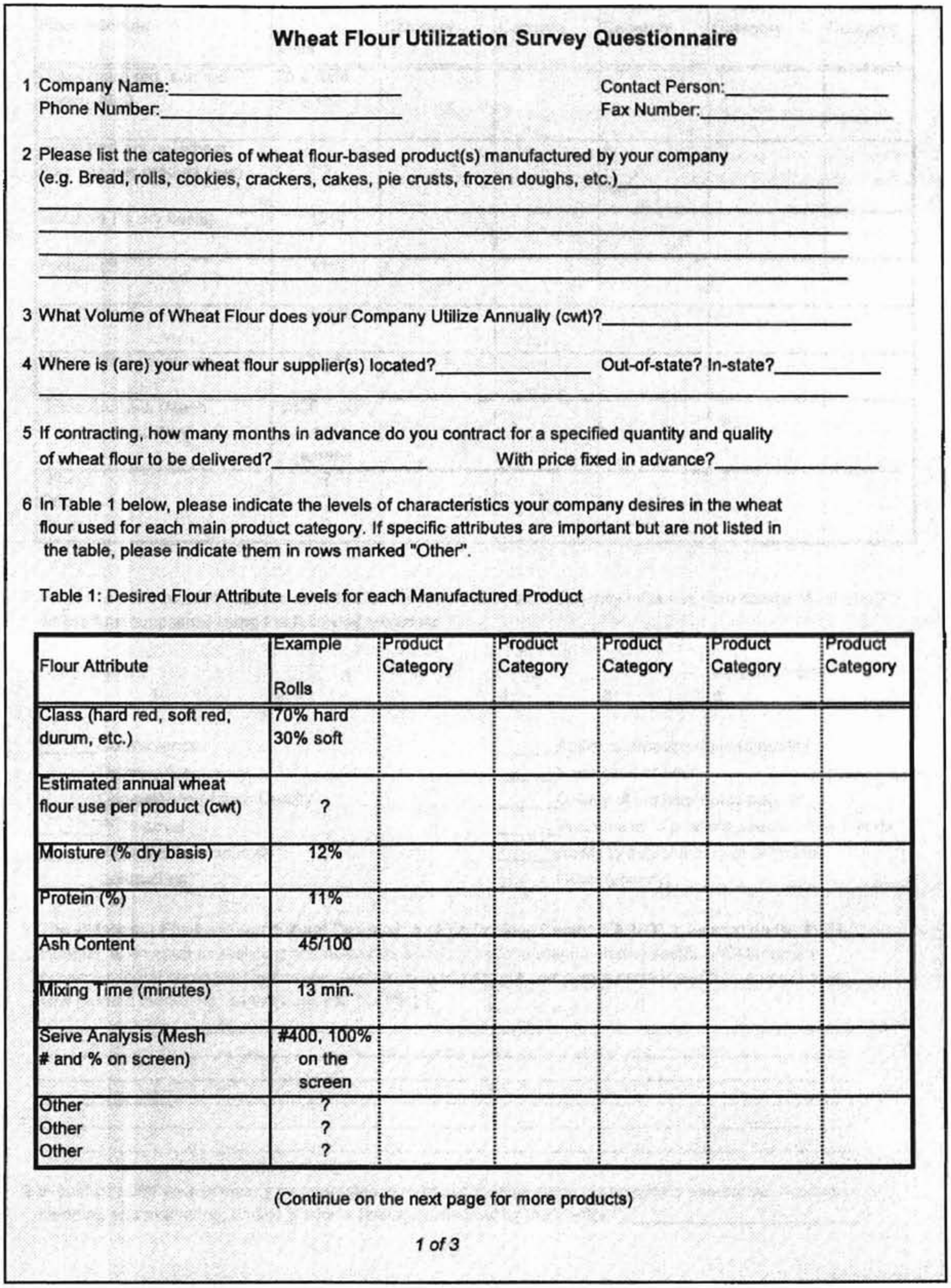
Model Version II

```
PROP(I,"SRW") = 100 ;
SOLVE WHEAT USING MIP MINIMIZING Z;
DISPLAY X.L;
*DISPLAY TOTWHT.L;
*DISPLAY TOTFLOUR.L;
DISPLAY R.L;
DISPLAY BYX.L;
DISPLAY BYF.L;
DISPLAY V.L;
DISPLAY PR.L;
DISPLAY NOM.L;
DISPLAY Y.L;
DISPLAY OWHEAT.L;
DISPLAY EWHEAT.L;
DISPLAY OFLOUR.L;
DISPLAY EFLOUR.L;
DISPLAY PERCAP.L;
```

APPENDIX C

DATA SOURCES

The Survey Instrument



Wheat Flour Utilization Survey Questionnaire

1 Company Name:________________ Contact Person:________________
Phone Number:________________ Fax Number:________________

2 Please list the categories of wheat flour-based product(s) manufactured by your company
(e.g. Bread, rolls, cookies, crackers, cakes, pie crusts, frozen doughs, etc.)________________

3 What Volume of Wheat Flour does your Company Utilize Annually (cwt)?________________

4 Where is (are) your wheat flour supplier(s) located?________________ Out-of-state? In-state?________________

5 If contracting, how many months in advance do you contract for a specified quantity and quality of wheat flour to be delivered?________________ With price fixed in advance?________________

6 In Table 1 below, please indicate the levels of characteristics your company desires in the wheat flour used for each main product category. If specific attributes are important but are not listed in the table, please indicate them in rows marked "Other".

Table 1: Desired Flour Attribute Levels for each Manufactured Product

Flour Attribute	Example Rolls	Product Category	Product Category	Product Category	Product Category	Product Category
Class (hard red, soft red, durum, etc.)	70% hard 30% soft					
Estimated annual wheat flour use per product (cwt)	?					
Moisture (% dry basis)	12%					
Protein (%)	11%					
Ash Content	45/100					
Mixing Time (minutes)	13 min.					
Seive Analysis (Mesh # and % on screen)	#400, 100% on the screen					
Other	?					
Other	?					
Other	?					

(Continue on the next page for more products)

1 of 3

Flour Attribute	Example Rolls	Product Category	Product Category	Product Category	Product Category	Product Category
Class (hard red, soft red, durum, etc.)	70% hard 30% soft					
Estimated annual wheat flour use per product (cwt)	?					
Moisture (% dry basis)	12%					
Protein (%)	11%					
Ash Content	45/100					
Mixing Time (minutes)	13 min.					
Seive Analysis (Mesh # and % on screen)	#400, 100% on the screen					
Other Other Other	? ? ?					

7 Please rate the relative importance of the following service factors that may influence your choice of wheat flour supplier(s) using the following 1-6 scale.

Not Important 1	2	3	4	5	Very Important 6

______Convenience
______Delivery Frequency
______Consistence of flour Quality
______Price Level
______Payment Terms/Credit
______Contracting

______Ability to produce desired quality
______Freshness of flour
______Quality of supplier sales people
______Willingness to produce specific flour blends
______Ability to adjust timing of deliveries
______Other (specify):______________

8 The Oklahoma Food and Agricultural Research and Technology Center (FAPRTC), located on the OSU campus, is devoted to assisting and further developing the food manufacturing sector of Oklahoma's economy. What could the Center and its staff do to assist your company's current and future operations, new product marketing, and/or business planning?

____
____
____
____
____
____

9 Would you and your company be interested in in-house training sessions on quality assurance, business planning and marketing, and/or products testing carried out by the Center?______________________

10 If you have any comments, please write them at the bottom of this page or on an extra sheet(s) of paper.
We deeply appreciate any additional feedback.

3 of 3

Table 2. Summary of Data Sources and Assumptions

Data Type	Source(s)	Comments/Assumptions
A. U.S. wheat production and flour disappearance trends	USDA's Wheat Yearbook Website (http://mann77.mannlib.cornell.edu/data-sets/crops/88008/2/)	
B. Instate wheat sources	Oklahoma Agricultural Statistics	Averaged over the period 1990-96
C. Proportions of HRW and SRW by county	O.S.U. Variety Survey report	Only actual harvested area considered
D. Wheat unit price at source ($/bu.)	Oklahoma Agricultural Statistics	Price received by the farmer averaged over the period 1984-97
E. Out-of-state wheat and flour sources by type	- Harwood, Leath and Heid, - Survey of Food Processors, FAPC	Harwood, Leath and Heid indicated U.S. wheat production areas by type. The survey helped to identify the areas flour is actually imported from.
F. Instate flour markets	- Oklahoma Directory of Manufacturers and Processors (Oklahoma Department of Agriculture, Oklahoma Department of Commerce), - Survey of Oklahoma Food Processors	The survey frame was obtained and concatenated from two independent surveys conducted by Oklahoma Dept of Commerce and Oklahoma Dept of Agriculture.

Table 2. Continued

Data Type	Source(s)	Comments/Assumptions
G. Annual flour use at each demand point, by type.	Survey of Oklahoma Food Processors	Indicated by respondents in the survey.
H. Flour unit price at out-of-state source proxies	Milling and Baking News	Averaged over the period 1984-96 (same period as for wheat prices)
I. Quantity of millfeeds used annually by each millfeed demand point.	Annual Summary of Official Feed Samples and Tonnage reports, Plant Industry and Commerce Service Division, Oklahoma State Dept of Agriculture, July 1995.	
J. Millfeed prices, fob flour mill	Oklahoma State University "Feed Commodity Bulletin." (http://ansi.okstate.edu/exten/feedbull/)	1996 prices
K. Existing flour processing plant sizes/capacities	- Current Industry Report, U.S. Dept of Commerce, - Telephone survey of Oklahoma Millers	Daily capacities (in cwt).

Table 2. Continued

Data Type	Source(s)	Comments/Assumptions
L. Annual fixed costs of building and operating the flour mills	Mill Management Economic Model (MMEM)	- Unit costs (per cwt flour) used in the MMEM for the 7000 cwt mill, here adjusted to the three mills (4900 cwt; 3000 cwt.), - U.S. GDP deflator used to update these costs to current period.
M. Other mill data - Flour processing variable costs, - Wheat-to-flour transformation rates	 MMEM MMEM	Constant unit costs assumed
N. Transportation rates	Telephone Survey of Oklahoma Shippers	Also assumed constant
O. Distances - from wheat sources to mill locations, - from mill locations to flour markets, - from mill locations to millfeed markets.	Rand McNally TripMaker software	In miles

APPENDIX D

THE MILL MANAGEMENT ECONOMIC MODEL

The Mill Management Economic Model (MMEM) was developed by researchers at Kansas State University (Flores et. al, 1989). This undertaking was motivated by the perceived need for a computer simulation model that would allow management of a typical flour milling enterprise to determine the possible impacts of various scenarios on milling operations. The researchers' goals were to:

1. Develop a general simulation model for the technical aspects of a flour milling process as a function of the market quality characteristics of the wheat to be milled;
2. Develop a mill management simulation spreadsheet model capable of reflecting economic variables that are associated with the process of milling flour and their impacts on mill economies; and
3. Combine the technical model and the management model into one that allows for the analysis of the wheat flour milling system.

The MMEM is a dynamic and integral tool that links the economic, technical, engineering and financial elements of the mill. This allows the impacts of different operating conditions on mill activities to be tested. The model consists of 5 operative steps and 50 tables implemented in an electronic spreadsheet. The five steps include operating characteristics, manufacturing, annual performance, financial plan, and long-term analysis. Each step consists of different tables, and each table groups the information related to a specific factor.

The MMEM can be a very useful tool in applications such as (Flores, 1989):

1. Conducting wheat flour mill feasibility analyses;
2. Making economic evaluations of the milling results of specific wheat types with standardized input values;
3. Teaching specific quantitative cases;
4. Estimating the economic impacts of various wheat purchasing alternatives by an importing wheat agency in a deficit area; and
5. Evaluating the economic impact of the new material and milling parameters.

The U.S. flour milling industry is characterized by low margins and high volumes. Within this competitive framework, any industry is hesitant to publish information about its operations (Flores, Posner and Deyoe). Therefore, the general economic model used in the Flores study was based on an updating of previously published information and general economic characteristics of the milling industry.

In particular, Flores, Posner and Deyoe updated the data presented by Eustace, Niernberger and Ward on fixed costs, payroll, and other cost items for one of the three mill sizes (7000 *cwt.*) that Eustace et al. had studied. To attain this, data from the *Construction Cost Index* of the Bureau of Census (1987), the *Economic Indicators* of the Joint Economic Committee (1987), and the *Bureau of Labor Statistics* (1987) were used. Current prices and costs for raw materials and products manufactured were obtained from market publications such as *Milling and Baking News* (1989), and *Kansas City Market Review* (1989).

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