AN INTERREGIONAL ANALYSIS OF THE UNITED STATES GRAIN MARKETING INDUSTRY

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Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
May, 1970

AN INTERREGIONAL ANALYSIS OF THE UNITED STATES

GRAIN MARKETING INDUSTRY

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PREFACE

This study was undertaken to analyze the complex interregional flow of grain and flour and to determine the flows associated with the optimum utilization of storage and processing facilities. The over-all objective of the study was to determine simultaneously the geographical flows of wheat, feed grain, soybeans, and wheat flour that minimize the total cost of storage, assembly, milling, and distribution for the grain marketing industry. The results were obtained by formulating mathematical models of the industry and generating solutions to these models by the use of linear programming procedures. The models include several, but by no means all, important spatial interrelationships involved in grain marketing, and one model incorporates the time dimension of the marketing process.

The author expresses appreciation to his major adviser, Dr. Leo V. Blakley, for his guidance, assistance and many valuable suggestions in conducting this study and preparing this manuscript. Appreciation is expressed to Dr. James E. Martin of Virginia Tech, the original Chairman of my advisory committee, for his invaluable assistance in planning the study and developing the appropriate models. Thanks are also given to the members of my advisory committee, Dr. James S. Plaxico, previous Chairman, Dr. John W. Goodwin, and Dr. Leroy Folks, for their helpful suggestions concerning the conduct of this study and the preparation of the final manuscript.

I would like to thank Dr. William A. Faught and Dr. Amos D. Jones, of the Fibers and Grains Branch, MED, ERS, USDA, for their support throughout the study and their helpful comments concerning the final manuscript. The assistance of other members of the Fibers and Grains Branch in collecting and interpreting data used in this study is also acknowledged.

A note of thanks is given to Mrs. Linda Dalton for her assistance and patience in typing earlier drafts of the manuscript and to Mrs. Sandy Workman and other members of the statistical laboratory whose efforts in preparing the input data for processing were invaluable. In addition, Miss Velda Davis is due recognition for her advice and typing excellence in preparing the final manuscript.

Finally, I wish to express appreciation to my wife, Nancy, for her patience and encouragement throughout my graduate program. Her understanding and support are gratefully acknowledged.

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CHAPTER I

INTRODUCTION

The geographic distribution of production and consumption of food and feed grains in the United States creates complex interregional flows of grains and grain products. This flow is not simply a physical movement of grain from surplus regions to deficit regions. Between the points of production and consumption, the activities of storing, processing, handling and transportation are necessary so that the grain will arrive at the various destinations in the form and at the time needed.

Knowledge concerning the optimum interregional flow and the competitive position of various regions of the United States is of prime importance to decision makers of the grain industry. These decision makers may be producers, elevator operators, grain processors, grain merchandisers, or others associated with the marketing of grains and grain products. Such knowledge can prove useful in determining the optimum location of stocks to minimize storage and distribution costs, and it could be useful to new firms entering the industry in suggesting which markets should be investigated first or where facilities should be located.

The transportation industry provides the dynamic link between the various producing and consuming regions as well as the link between the many firms and agencies in the marketing system. The importance of the transportation system to the grain industry can be illustrated by considering transportation's contribution to the value of grain. Transportation charges accounted for an average of 10 percent of the value of wheat received by rail at Minneapolis, Kansas City, Portland and St. Louis during 1959.[1] The comparable figure for corn received by rail at Chicago was 12 percent. In view of these data, it becomes apparent that a non-optimal shipment pattern can result in a sizable increase in the total charge for marketing grain.

A goal of minimizing the total charges involved in handling, storing, processing and transporting grain between the producer and consumer is very desirable. These charges determine the price spread between the producer and user, and a reduction in these charges can benefit the producer and/or consumer in a competitive situation.

The Problem

Adjustment to changing market conditions is a continuous process for grain processing and marketing firms. The efficiency with which these adjustments are made often determines the profitability of particular activities and the future of the industry affected. In the past, relatively inflexible institutional arrangements and constraints have permitted few adjustments to be made in the overall grain marketing system.

There are two industries of the grain marketing system that have been faced with serious adjustment problems during the last decade. They are the grain storage industry and the wheat flour milling industry. The factors giving rise to the adjustment problems faced by these industries will be discussed below.

The central problem of the storage industry is one of over-expansion in some sections of the United States. The carryover of all major grains increased rapidly in the late 1950's until stocks of wheat and four major feed grains reached an all-time high of 4.6 billion bushels at the end of the marketing year for the 1960 crop (Table I). Wheat and corn stocks reached levels of 1.4 and 2.0 billion bushels, respectively, and these levels represented about a 200 percent increase over the quantities carried over in 1951. Most of this accumulation was in the form of stocks owned or controlled by the Commodity Credit Corporation (CCC). To obtain storage space for these stocks, an attractive storage rate was offered by CCC in the late 1950's, and this encouraged the building of many elevators. Subsequent to 1961, aggressive export programs by the government and larger commercial exports were effective in reducing the carryover to more desirable levels. In 1966, the stocks of wheat and the four feed grains had been reduced to 2.2 billion bushels (Table I), a reduction of 52 percent since 1961. The reduction left the storage industry in an over-expanded position, and the loss of storage revenue put many elevators in an unprofitable position and set the stage for some to exit the industry. Thus, there is a need to study regional storage requirements and determine the regions in which excess capacity is a problem.

The other industry involved in grain marketing that faces serious adjustment problems is that of the wheat flour milling industry. Transportation is unavoidably a key element in the milling industry, and the transportation rate structure (the relationship between the transportation cost of wheat and of flour) determines to a large extent whether milling is carried on near wheat production areas or near flour

TABLE I

CARRYOVER STOCKS OF WHEAT AND THE FOUR MAJOR FEED GRAINS IN SELECTED YEARS, UNITED STATES

Type of Grain	Marketing Year Ending in 1951	1956	1961	1966
	million bushels			
Wheat[a]	400	1,033	1,411	535
Corn[b]	740	1,165	2,016	840
Sorghum[b]	38	81	702	392
Oats[a]	286	346	324	316
Barley[a]	94	117	152	105
Total	1,558	2,742	4,605	2,188

[a]Stocks as reported on July 1.

[b]Stocks as reported on October 1.

Sources: U. S. Department of Agriculture, Food Grain Statistics Through 1967, Economic Research Service Stat. Bul. No. 423 (Washington, April, 1968), p. 10, and Feed Statistics Through 1966, Economic Research Service Stat. Bul. No. 410 (Washington, September, 1967), pp. 26-29.

consuming centers. For many years the flour milling industry depended to a great extent on railroads for transportation services. These transport services for wheat and flour have been priced at the same rate per hundredweight (parity rates) or at the same rate from wheat origin to flour destination regardless of mill location (transit rates). The former rate system favored milling away from the consuming market in favor of a wheat supply orientation and the latter effectively limited the market area of mills located at flour destination points (see Chapter II). Thus, the milling industry of the Eastern and Southeastern states was limited to small, localized mills while mills in the mid-western and plains states flourished. There were some exceptions such as Buffalo where the lake rates on wheat were low enough to make this milling location competitive.

In recent years several developments have altered the relationship between wheat and flour rates. The most important factors are: (a) increased barging and trucking of wheat to market oriented mills, (b) sub-parity hopper-car wheat rates (Big John rates), and (c) sub-parity export wheat rates. A final factor that actually is a combination of (a) and (b) above is a court ruling in the famous "Barge Case" of 1958 (Docket No. 30844) which determined that shipments moving to points on the Tennessee River by barge were entitled to continuation by rail to destination at rates proportionate to the all rail rates from Mississippi River crossings. In other words, if the barge movement covered two-thirds of the distance of an all rail movement then the ex-barge rail rate would be one-third of the all rail rate. This ruling extended the benefits of low cost barge transportation to off-river destinations in the Southeastern states and permitted mills at locations in the South Atlantic region to be competitive. These transportation factors will be more fully discussed in Chapter II.

The factors stated above related to rates and technological advances such as the "Big John" hopper-cars have tended to reduce point-to-point bulk rates for transporting wheat over the years. On the other hand, flour rates have not declined or have declined less proportionately. Such changes in the transportation rate structure affect the least-cost location of flour milling from a transportation standpoint as well as the competitive position of mills in various regions. Thus a study of interregional competition is needed to guide locational adjustment and depict optimum flow patterns for wheat and flour given existing transportation rates.

Ordinarily, constructed transportation costs rather than actual charges are employed in spatial analyses and intermodal competition is ignored. Consequently, the effects of factors other than distance on transfer costs usually are neglected. In this study published point-to-point rail and barge rates were employed in an attempt to more realistically depict the existing spatial relationships involved in marketing grain and grain products. Published truck rates were not readily available so mathematical equations were employed to estimate truck transportation rates.

Objectives of the Study

The purpose of this study is to evaluate the interregional aspects and competitive structure of the grain marketing industry. This will provide information and planning data for marketing, transportation and processing firms, and policy makers. These firms should find this information useful in guiding decisions concerning market operations and firm expansion. The specific objectives of the study are to:

(1) Develop an operational model capable of analyzing a multifactor, multiproduct, multiregion, and multistage transhipment problem of the United States grain marketing system.

(2) Determine efficient distribution patterns which will minimize total cost of storage, acquisition, processing and distribution for the grain marketing system, with existing structure and competitive conditions.

(3) Determine intermarket and shipping point price relationships for grain by computing equilibrium price differentials between major markets and shipping points and evaluate the competitive position of various production and consumption regions.

(4) Determine the competitive position of flour mills in various regions and estimate the savings that would result from a relocation of mills consistent with the low bulk rates on wheat to many destinations.

(5) Analyze the effects upon the efficient distribution patterns determined above when minimum inventory levels are maintained at the various grain destinations.

(6) Study the optimum utilization of storage capacity and determine quarterly interregional flows of grains consistent with the available regional storage capacity.

The remainder of this study is divided into six chapters. Chapter II includes a review of early developments in the theory of location and a discussion of the transportation rate structure as it relates to industrial location.

In Chapter III, the general transportation and transhipment models are discussed and previous applications of these models are reviewed. A transhipment model which incorporates the activities of storage and processing into a multifactor, multiproduct, multiperiod framework is developed, and hypothetical problems involving single and multiple time periods are formulated and solved. The mathematical definition and selected assumptions of the national model are presented.

Chapter IV contains a specification of the regional demarcation employed in the study. Once the regional demarcation and regional basing points are established, the necessary regional data for implementing the model developed in Chapter III are presented. The necessary data relate to estimates of supplies, demands, capacities and marketing costs and/or charges.

Chapter V contains the results obtained from three annual analyses. These analyses are related to the satisfaction of Objectives 2-5. The results of the time-staged model are presented in Chapter VI and regional storage capacity requirements are determined.

Finally, Chapter VII contains a summary of the study and a discussion of the conclusions and implications of the analyses. The limitations of the study are also considered as well as some suggestions for future research with models similar to the model developed for this study.

FOOTNOTES

[1] Bruce H. Wright, "Transportation and the Grain Industry," _Marketing Grain, Proceedings of the NCM-30 Grain Marketing Symposium_, North Central Regional Research Publication No. 176 (Lafayette, January, 1968), p. 109.

CHAPTER II

LOCATION THEORY

Location theory is important to this study because it provides a theoretical framework for problem formulation and analysis. In addition it aids one in understanding why particular patterns of location have developed in many industries that are involved in marketing grains and grain products in the United States. Location literature is large and growing, and even a brief mention of all notable contributors exceeds the available space that may be devoted to the subject in this study. Therefore, this discussion will be limited to the classical contributions in the "fixed market" approach and the "market area" approach to location.

The approaches listed above suggest the two principal types of problems with which traditional location theory has been concerned. First, where does economic activity locate in order to maximize its profits assuming that markets are fixed? Secondly, where is it most profitable for the firm or industry to market its products assuming a given or existing locational pattern? Both types of problems have been approached from a least-cost viewpoint.

The pioneering works of J. H. von Thunen and Alfred Weber are considered classical in the "fixed market" approach to location. Frank A. Fetter and August Losch have made significant contributions in the "market area" approach to location. Other theorists have elaborated upon and/or refined much of the work of these men; however, this discussion will be restricted mainly to the work of the above pioneers.

The Fixed Market Approach

The theoretical work of von Thunen was one of the earliest efforts to specify locational patterns as they are related to transportation costs.[1] His theory assumed an "isolated state" consisting of a central city surrounded by a homogeneous plain of farm land. The city represented the only available market for the agricultural products produced on the plain, and the farmers on the plain represented the only source of supply for the city. The farm sector was purely competitive, and farmers were free to engage in whatever type of agriculture they chose. This theory assumed that only one form of transportation was available and was equally accessible to all farmers for moving produce to the city. Freight rates were assumed to be set on a straight ton mileage basis regardless of the kind of product hauled. The theory was directed to the problem of what kind of agricultural production would occur in what parts of the plain. Transportation costs were the key variable in von Thunen's analysis.

The main assumptions of von Thunen's model may be stated explicitly as: (1) the farmers are profit-maximizers, (2) market prices are given and are the same to all farmers for products delivered to the city, (3) profit equals market price minus production costs and transportation costs, and (4) transportation costs vary directly with distance from the city.

The fourth assumption implies that all farmers equi-distant from the city pay the same transport costs for the same product. Thus, any crop which is most profitable at any given location with a particular method of production is also most profitable at all other locations an equal distance from the market. The outward boundary for any crop would be where profits equal zero. In cases where two or more crops at the same distance from the city would yield profits, the most profitable alternative was chosen. Thus crops are grouped into a series of distinct concentric circular zones.

The results of von Thunen's analysis indicated that perishable products and products heavy in relation to their value will be produced near the market, while items which are less perishable and are more valuable per unit of weight will be produced farther away.

Marginal analysis and factor-product relationships were incorporated into this analysis with an intensity of cultivation factor. Since net farm prices were gross city prices minus transport costs, the net price for a given unit of a particular product decreases the further a given farm is from the market. Thus, land near the city could be made much more profitable with intensive applications of variable resources (labor and capital), and extensive agriculture is more profitable as distance from the market increases. The above principle simply states that maximum net earnings are attained when the intensity of cultivation is proportionate to the net price to farmers (city price minus transportation costs).

Although von Thunen's theory was a notable contribution, changing conditions have greatly reduced its usefulness as an operational model. In addition, the assumptions concerning a central "isolated city" and the existence of a uniformly fertile plain are never duplicated in the real world. Nevertheless, his interest was in changes in crops and in methods of cultivation which occurred as distance from the central city increased, and his model was very useful in studying the effects of transportation costs on economic rent and land use patterns. Friedrich states that "Thunen's theory of agricultural location was a by-product of his effort to determine which kind of production would best be carried on at a given place."[2]

While Thunen was interested in location of agricultural production, Alfred Weber addressed his analysis to the location of manufacturing and processing industries and the factors determining location.[3]

Weber identifies several types of factors that influence industrial location. These factors may be general, affecting all industries; or they may be special, affecting only certain industries. According to Weber, all locational factors (whether general or special) may be classified into (1) regional factors and (2) agglomerative factors.[4] The regional factors determine the regional distribution of industry while the agglomerative factors determine concentration of industry at certain points within the region.

The regional factors which Weber identifies as being important in determining industrial location are factors of cost: the costs of transportation and geographical differences in labor costs. The agglomerated factors are quite independent of geography and may operate to concentrate industry at certain points within a region or disperse it over a wide area. He suggests that agglomerating tendencies are simply an alternating force within each region once the regional distribution has been determined by costs of transportation and labor. Those variables reflecting natural and social conditions in location are assumed fixed. In Weber's methodology, he first assumes labor costs constant at all locations and studies the influence of transportation costs alone and then relaxes the constant labor costs assumption to determine the effects of these, once the optimum location pattern has been established with transportation costs as the only variable. He felt that industrial location was primarily related to transportation costs, but that differing labor costs between regions could be important in many cases where transportation cost differences for two locations were small.

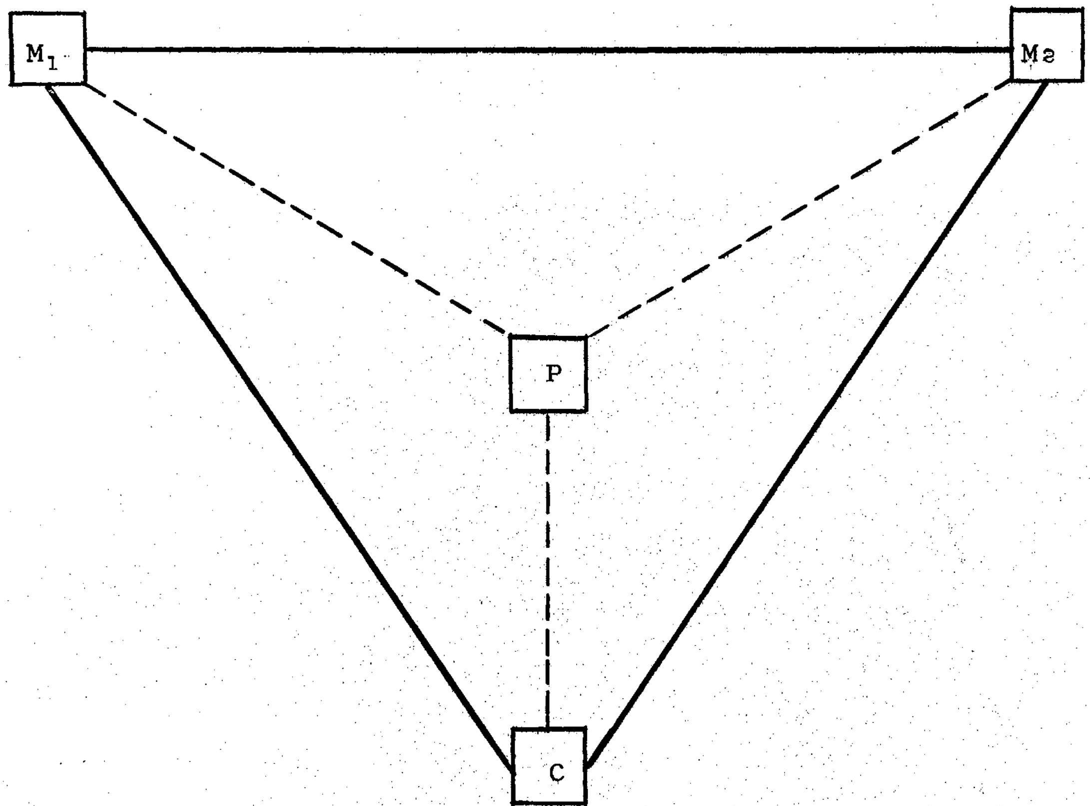
In order to keep the variables to a manageable number, Weber assumed that the prices of fuel and raw materials were equal at all locations. To accomplish this, the differences in the prices of materials at different deposits were expressed as differences in costs of transportation.[5]

Like von Thunen, Weber assumed equal transport accessibility and straight ton-mile rates with no distinction for type of product. He also assumed, as stated above, that prices of fuel and raw materials were equal at all deposits. Labor was assumed to be geographically fixed and the supply at a particular location perfectly elastic. The location of markets, the location of raw material deposits, and the requirements at various consuming centers were fixed and known. With fixed supply points and market locations, Weber sought to determine where processing enterprises should be located in order to minimize total transfer costs of materials and finished products plus labor costs involved in processing.

Weber used several terms to describe raw materials as to availability and processing characteristics. In terms of availability, materials that were available in all locations were called "ubiquities" while materials found only in certain localities were said to be "localized." Materials that do not lose weight during processing were referred to as "pure" while those losing weight during processing were referred to as "gross" materials. Many different situations may be formulated under Weber's theory depending upon what one assumes regarding the number of raw materials involved and their characteristics.

To illustrate Weber's model, consider a situation involving one market and two raw materials. Also, assume that both raw materials are gross and localized at different sources away from the market. This situation is depicted in Figure 1 where M_1 and M_2 represent raw material sources one and two, respectively, and C is the market where the product is consumed. Except in exceptional cases where one material happens to be so important as to offset the increased transport distance of the other material, ton-mileage will be minimized if processing takes place somewhere within the triangle such as location P. Just where within this triangle the least-cost location will fall will be determined by a combination of the relative quantities of each of the materials used and by their relative weight-losing characteristics. If weight losses are the same for both materials, processing will be located nearer the material used in greatest quantity, and it will be nearer the source of the greatest weight loser when the materials are combined in equal quantities. Also, the greater the weight loss, the farther from the market processing will locate.

Thus, weight-losing materials draw industries toward the raw material sources. In order for processing to be located at a raw material source, the weight of the material must be greater than the sum of the other materials plus the weight of the product.[6] Weber is



M1 - Source of Raw Material 1

M2 - Source of Raw Material 2

P - Location of Processing

C - Location of Market

---- Transportation Route

Figure 1. Weber's Locational Triangle[6]

generally given credit as being the first writer to fully understand and systematically incorporate into a locational theory the concept of weight-losing raw materials.

The "Locational Triangle" presented above is applicable only to situations where the combined number of raw materials and markets is three. When more than three points are involved, the problem of finding the point where total ton-mileage of raw materials and finished product is minimized is identical with finding the equilibrium position or center of gravity resulting from the relative weight pulls of sources and markets. These weight pulls are proportional to the quantities to be moved.

After fully investigating the effects of transportation on location, Weber then relaxed the assumption of equal labor costs in all regions and analyzed the effects of locational differences in labor costs upon the optimum location determined by minimizing transport costs. He concluded that:

> A location can be moved from the point of minimum transportation costs to a more favorable labor location only if the savings in the cost of labor which his new place makes possible are larger than the additional costs of transportation which it involves.[8]

Weber's analysis of those factors affecting the location of manufacturing was a partial equilibrium approach. Like von Thunen, his assumptions were restrictive and his variables few in number. His major contribution was that of showing the importance of transportation costs in determining the location of economic activity. His methodology also represented a sound foundation upon which later writers could expand, refine, and build in developing location theory.

The Market Area Approach

The other major branch of location theory is known as the "market area" approach. This approach, in contrast to the "fixed market" approach of von Thunen and Weber, takes the location of production as given. The most notable contributors in this area are Frank Fetter,[9] an American economist, and August Losch,[10] a German economist. This branch of the theory considers the situation where several producers compete in a marketing area, and it attempts to determine the particular sub-region within the marketing area that each serves, assuming that the entire output of all producers is consumed in the area.

The "laws of market areas" as set forth by Fetter in 1924 permit useful insights into some of the ways in which the structure of transport rates influences the location of producers in relation to their markets. Consideration was also given to the effects of a reduction in either production cost or transport cost to enlarge the market that can be economically served by a producer at a particular location.

Losch is generally credited as being the first writer to present a general equilibrium system describing the interrelationship of all locations. The system is too abstract to be applicable, but his theoretical framework was a great contribution in the development of location theory. He was critical of the cost orientation to location expressed by earlier writers. He maintained that cost alone could not be used to determine actual location and that net profit is the final and sole determining factor in location.[11] He considered the assumption of an inelastic demand as the major weakness of Weber's theory.[12] He relaxed this assumption and studied industrial location as it is affected by costs and demand. He realized that his system of equations was too all-inclusive to be applied to particular plant location problems. He suggested that in practice the determination of optimum plant location could only be approached on a trial and error basis. This involves evaluating alternative locations and selecting the one yielding the greatest net return. The one selected may not be the optimal but only the best of the alternatives considered.

Stolper asserts that "Losch's discussion of the nature of economic regions is probably his most original contribution."[13] In developing his theory of "the market area" he assumes that raw materials are evenly distributed throughout a wide plain and that the plain is homogeneous in all other respects (including the distribution of population).[14] Each producer in the plain has a natural market area within which he has a delivered cost or price advantage over all competitors when all costs of production and transportation are included. The problem is to determine the size and shape of each producer's natural marketing area.

To illustrate marketing area determination, consider a case of two sellers, X and Y, of the same product. For simplicity, it will be assumed that transport is equally available between any producer and all potential buyers on a straight ton-mileage basis and that all buyers have identical demand curves for the product under consideration. If production costs are equal, each seller has an advantage at all buying points closer to his location than to his competitor's location. In this situation the boundary between the two marketing areas would be a straight line of equal cost midway between the two sellers. This is depicted as line a,a' in Figure 2. General freight rate increases or decreases will have no effect on the boundary as long as production

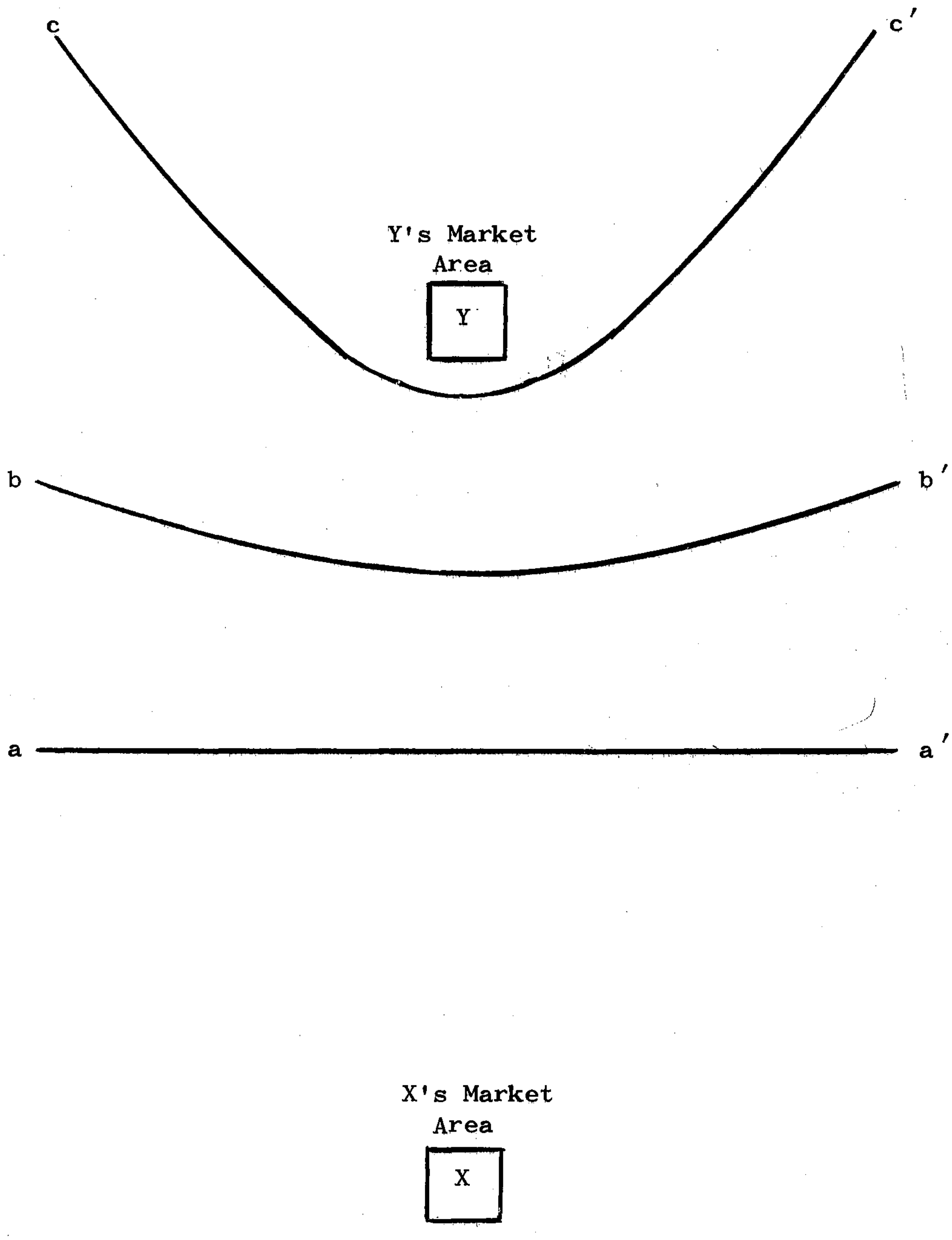


Figure 2. Market Areas of Two Producers Under Various Cost Assumptions

costs are equal. Now relax the assumption of equal production cost by supposing that X's production costs are lower than Y's. The line of equal total cost will be closer to Y and take the form of a hyperbola bent around the location with higher production cost. Such a line is illustrated by b,b' in Figure 2. Thus the manufacturing cost disadvantage is offset by savings in transportation costs. Under this situation, a general decrease in transportation rates per mile will tend to further restrict Y's market area, and the boundary line will move closer to Y. This is illustrated by line c,c' (Figure 2). In general, a disadvantage in production costs increases in a relative sense as the per-mile cost of transportation decreases.

In the case of many sellers having equal production cost, Losch demonstrated that hexagonal economic regions would develop, each having one seller located at the center.[15] This form of market area enables each seller to maximize his profits over a given geographic area, and by selling more at lower transportation costs, total sales by all sellers in the plain are maximized. However, differences in production cost among producers will alter such a locational pattern.

Hoover points out that this approach can also be applied to the determination of a firm's supply area.[16] Hence, the boundary lines deciding the supply area among competing firms are determined by transportation costs and the delivered price at the processing plants.

Location theory, transportation costs and manufacturing costs are inseparable. Traditional locational theory assumes given transportation facilities equally accessible to all locations, and straight ton-mileage rates were used by all writers. In addition, blanket rates, transit privileges, existing carrier route patterns, intermodal cost differences, and many other transport factors that affect location were not considered. Even though many of these real world factors were omitted from these analyses, these writers made great contributions in developing the theory of location. Perhaps their greatest contribution was in calling attention to the influence of transportation costs upon the location of economic activity.

Further Elaboration of Transportation and Location

The works of location theorists discussed above are quite useful in setting forth the relationships between transportation costs and the location of economic activity. However, many transport factors such as graduated rate structures, transit rates, value of service pricing, existing carrier route patterns and intermodel competition can significantly alter the nice transportation rate structure assumed by these writers. Consequently these factors may become important in influencing location.

Perhaps the factor of more general importance in an industrial society is that of a graduated rate structure. Isard states that "one of the most devastating shortcomings of Weber's model has been its inability to encompass realistic transport rate structures less than proportional to distance."[17] Weber's assumption of a straight ton-mileage rate structure was probably realistic at the time of his writing, so he should not be criticized too severely. Nevertheless, such an assumption is very unrealistic in modern times.

Isard's concept of transport inputs is a means of combining Weber's transport-orientation and firm production theory to handle the graduated rate structures of modern time. The "transport input" is the movement of a unit of weight over a unit of distance and is treated as any other input in the production process. Thus a spatial dimension is added to production theory when these inputs are included in the firm's transformation function. Since transport inputs for each raw material and product are viewed as any other factor of production, the analysis is essentially the traditional factor-factor model. He states the equilibrium condition as follows:

> At the point of minimum transport cost, the marginal rate of substitution between any two transport inputs, the other held constant, must equal the reciprocal of the ratio of their prices, namely, the corresponding transport rates.[18]

In this framework, production theory is capable of accounting for the locational factor. Isard graphically demonstrates his technique for determining the spatial equilibrium of the firm in a situation involving two raw materials by constructing transformation lines and iso-outlay lines for particular rate situations.[19]

Isard's analysis offers an additional advantage in that terminal and loading charges may be incorporated. Further, the application of different transport rates to the movement of raw materials and finished products can be incorporated into the problem. This consideration is extremely important for many industries such as the flour milling industry where the rate structure is evolving into one based on cost-of-service. These common rate considerations were essentially ignored by earlier writers. Isard's objective was to synthesize, extend and refine those partial locational theories already formulated into a more general theory of location. His synthesis provides greater insights into the location of economic activity in a real world setting. Isard admits in his preface that his general theory is not very useful in handling real world problems, but this was not his objective.[20]

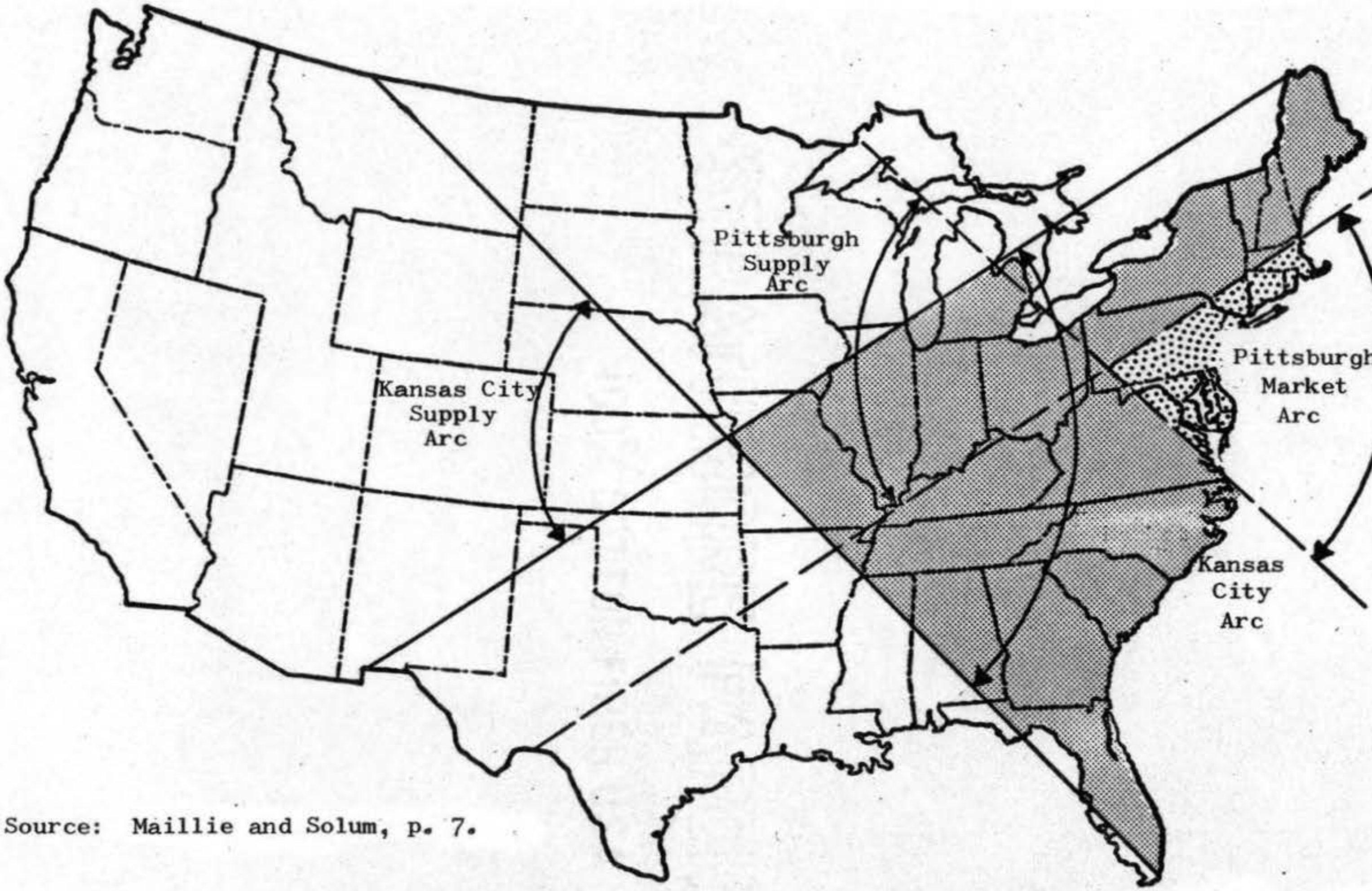
Another transport factor of importance in grain marketing and one ignored by location theorists is the transit rate system of American railroads. This system has been extremely important in influencing the development of locational patterns present in the American flour milling industry today.

In the early days of milling, a general practice developed of hauling flour and wheat at the same rates. Since there is approximately a 27 percent weight loss in milling wheat into flour, this rate structure provided a tremendous locational advantage for mills located in the wheat growing regions of the country. The parity rate policy on wheat and flour amounted to a 27 percent freight cost advantage for a mill at St. Louis in shipping flour to eastern markets as compared with mills located near the consumption centers. This locational pattern is one that would be expected from the Weberian model.

In the early 1900's, the railroads introduced the "transit" rate system. The transit rate system was designed to neutralize any advantages or disadvantages which accrued to any mill solely by virtue of its particular location along a line between wheat field and flour market. Under this system, the total freight cost from wheat origin to flour destination would be identical regardless of whether the flour mill was located in the wheat supply area, near the flour market, or anywhere in between. The transit "privileges" applied to storages as well as milling. Transit was based on the theory that the transportation service to and from the transit point is in reality a continuous shipment from point of origin to final destination of the same commodity or its product. This rate system permitted millers in various locations to compete on equal terms regarding transport cost.

Although the rate system neutralized transportation cost advantages, with respect to rail shipments, it did not make all mills equally competitive in a given market. In fact, it had a suffocating effect on the eastern milling industry by limiting its market area.[21] To illustrate, consider a situation involving a mill at Kansas City and one at Pittsburgh (Figure 3). Transit privileges operate only on substantially straight lines between wheat supply points and flour markets. The Kansas City mill draws wheat supplies within its transit arc to the west and can obtain the transit rate on flour shipments within its corresponding market arc to the east. The supply arc and market arc for the Pittsburgh location are determined in a similar manner. Pittsburgh has access to a much larger supply region than Kansas City, but its transit arc to the east -- its market area -- is extremely limited compared with Kansas City's. Thus the Kansas City mill enjoys competitive market immunity from the Pittsburgh mill throughout most of the Eastern United States, because transit rates do not apply to east-west or off-line shipments. If the Kansas City mill enjoyed economies of size or other processing cost advantages, it might even be able to sell flour at a lower price than the Pittsburgh mill in the latter's marketing area.

Deviations from the Weberian model are also produced by the availability of barge transportation. In the Southeast, for example, mills located at barge points along the Tennessee River have a significant competitive advantage because of the low cost of barging wheat into the region. The availability of barge transportation may also keep transportation rates via other modes of transportation below what



Source: Maillie and Solum, p. 7.

Figure 3. The Effective Marketing Area of Flour Mills Under the Transit Rate System

they might otherwise be in the absence of barge competition. The benefits of barge transportation are not restricted to river-point locations, but can and do accrue to other locations through barge/rail or barge/truck combination movements.

This discussion does not exhaust the list of transport factors that result in deviations from the locational patterns depicted by the locational models. Many other factors could be mentioned but these are some of the more important from the standpoint of grain marketing. It is obvious that in the case of the flour milling industry, no general locational pattern exists. In situations where parity rates exist on wheat and flour, the industry tends to be located near wheat supplies. In situations where low rates exist for wheat (when barge and barge/rail combinations are possible) the locational pattern will reflect a market orientation. Lastly, in situations where the transit rate system is effective, a mill may locate at wheat origin, flour destination, or somewhere in between. In the latter situation the optimum location will be determined by factors other than transportation cost.

FOOTNOTES

[1] J. H. von Thunen, The Isolated State (Chicago, 1960).

[2] C. J. Friedrich, in his introduction to the translation of Alfred Weber, Theory of the Location of Industries (Chicago, 1929), p. XXII.

[3] Alfred Weber, Theory of the Location of Industries (Chicago, 1929).

[4] Ibid., pp. 20-21.

[5] Ibid., p. 34.

[6] Ibid., p. 57.

[7] Ibid., p. 55.

[8] Ibid., p. 103.

[9] Frank A. Fetter, "The Economic Law of Market Areas," Quarterly Journal of Economics, XXXVIII (1924).

[10] August Losch, The Economics of Location (New Haven, 1954).

[11] Ibid., p. 27.

[12] Ibid., p. 28.

[13] Wolfgang F. Stolper, in his introduction to the translation of August Losch, The Economics of Location (New Haven, 1954), p. X.

[14] Losch, p. 105.

[15] Ibid., p. 110.

[16] E. M. Hoover, The Location of Economic Activity (New York, 1948), p. 48.

[17] Walter Isard, Location and Space Economy (New York, 1956), pp. 108-109.

[18] Ibid., p. 224.

[19] Ibid., pp. 105-112.

[20]Ibid., p. VIII.

[21]Jeff Mailee and Dale Solum, An Analysis and Evaluation of Factors Which are Deleterious to the Competitive Interest of the Mid-American Wheat Flour Milling Industry (Kansas City, 1968), pp. 5-8.

CHAPTER III

THE MODEL

The model employed in this study is usually referred to as the transhipment model. Basically, this model is an outgrowth of the two-dimensional transportation model which was designed to minimize transportation charges incurred in shipping a product from each of several origins to fulfill the requirements at each of several destinations. The model involved a single product with quantities supplied and demanded in each region known, and shipments were direct between origins and destinations.

The transhipment variant of the transportation model is formulated such that shipments of a product by a sequence of points is allowed rather than just from "m" surplus regions to "n" deficit regions as is the case of the basic transportation model. For example, in the model employed in this study, the formulation is such that grain may move through commercial storage and/or processing facilities before being shipped to satisfy the various demands for grain and grain products. This model was chosen primarily because it is reasonably flexible in solving spatial equilibrium problems, and the cost and other data processing advantages of solving problems that can be formulated within the framework of the transportation model are very significant.

The transportation model is a special case of the general linear programming model and may be solved by linear programming techniques other than transportation algorithms when desirable. The transportation model has numerous business and economic applications which have nothing to do with transportation. Nevertheless, it was developed for problems in which spatial considerations play a significant role, and this is the type of problem that is of interest in this study.

The General Transportation Model

The objective of the model is to minimize a linear function subject to certain linear restraints. The conventional mathematical definition of the problem may be stated as follows:

$$\text{Minimize} \quad C = \sum_i \sum_j C_{ij} X_{ij}, \quad \begin{matrix} i = 1, 2, \ldots, m, \\ j = 1, 2, \ldots, n, \end{matrix} \tag{1}$$

subject to the constraints

$$\sum_j X_{ij} = S_i \tag{2}$$

$$\sum_i X_{ij} = R_j \tag{3}$$

$$X_{ij} \geq 0 \tag{4}$$

$$\sum_i S_i = \sum_j R_j \tag{5}$$

where m is the number of supply points, n is the number of demand points, S_i is the supply of a commodity at the i^{th} location, R_j is the demand for the commodity at the j^{th} location, C_{ij} is the cost of transferring a unit of the commodity from location i to location j, and X_{ij} is the number of units of the commodity shipped from S_i to R_j in order to minimize the total cost of the operation.

A generalized matrix format of the transportation model is presented in Figure 4. The location of various elements of costs, supplies, and demands are depicted in Section A. The format consists of "m" supplies, "n" demands, and "m × n" cost elements (C_{ij}). The format of the corresponding matrix of shipments (X_{ij}) is presented in Section B.

As is indicated by Equation (5), total supply must equal total demand. If total real supply exceeds total real demand, a dummy demand must be included. Shipments to the dummy demand from any supply location incur no costs and merely represent inventory at points of shipment after real demands have been satisfied. Likewise, if total real supply is less than total real demand, a dummy supply must be included. Shipments from this supply incur no costs and represent unfilled demands.

Basic Assumptions

There are four basic assumptions associated with the transportation model:

(1) There is an objective to be maximized or minimized (Eq. 1).

(2) The supplies at various origins and the demands at various destinations are known.

(3) The per unit cost of converting resources to products or moving the commodity from origins to destinations is known and is independent of the number of units converted or moved.

	Destinations 1	2	...	n	S_i
Origins 1	C_{11}	C_{12}	...	C_{1n}	S_1
2	C_{21}	C_{22}	...	C_{2n}	S_2
⋮	⋮	⋮		⋮	⋮
m	C_{m1}	C_{m2}	...	C_{mn}	S_m
R_j	R_1	R_2	...	R_n	

Section A. Cost Matrix

	Destinations 1	2	...	n	S_i
Origins 1	X_{11}	X_{12}	...	X_{1n}	S_1
2	X_{21}	X_{22}	...	X_{2n}	S_2
⋮	⋮	⋮		⋮	⋮
m	X_{m1}	X_{m2}	...	X_{mn}	S_m
R_j	R_1	R_2	...	R_n	

Section B. Shipment Matrix

Figure 4. A Generalized Matrix Format for the Transportation Model

(4) The commodity under consideration is homogeneous. Thus, quality differences that exist at different localities are not accounted for.

Development and Application

The transportation model was originated by Hitchcock in 1941.[2] His problem was to establish the least costly manner of distributing a product supplied by several factories to a finite number of cities. His method involved introducing and eliminating parameters to obtain an optimal solution. Later, Koopmans further refined and applied the model as statistician with the Combined Shipping Adjustment Board during World War II.[3] The theory of optimum allocation of resources was applied to world shipping to promote an efficient utilization of movable transportation equipment.

Samuelson extended the Hitchcock-Koopmans formulation into a more general spatial equilibrium problem.[4] This formulation incorporated the demand and supply curves of two or more localities and converted the standard transportation problem into a maximization problem of equilibrium analysis. The model was designed to determine equilibrium prices as well as interregional commodity flows given constant per unit transport cost.

Numerous applications of the transportation model have been made since these early works. Some of these will be briefly discussed to illustrate the types of applications that have been made in agricultural economics.

One of the first important applications in the field of agricultural economics was made by Henry and Bishop.[5] A transportation model was employed to determine the best possible adjustment of national broiler markets in 1954 and 1955. The price differences between markets and the broiler shipping pattern between supply areas and consuming centers were determined. The optimum shipping patterns were obtained for 57 regions by minimizing transportation costs.

Shortly after the above study, a transportation model was formulated to find the best markets for North Carolina eggs and the locational advantages enjoyed by North Carolina egg marketing agencies relative to their counterparts in competing areas.[6] Optimum intermarket flows among 88 regions were determined. Regional production and consumption as well as interregional transfer costs were predetermined.

Koch and Snodgrass used a transportation model to find interregional product flows, price equilibriums, and optimum resource allocation for the tomato processing industry.[7]

Judge et al., have applied similar models to the feed grain economy. In an analysis of the corn sector, the impact of alternative actions by loan-eligible producers and Commodity Credit Corporation administrators on the marketing and distribution of corn in the 1961-62 marketing year was measured.[8] Estimates of regional price differentials, demands, supplies, and interregional flows for corn under alternative time periods and assumptions were determined. In a follow-up analysis of the feed grain economy, optimum flow patterns and price differentials for each of the four feed grains were determined.[9] Attention was also directed to the optimum storage location of each feed grain under conditions of equilibrium. However, a storage sector was not included in the model, and estimated storage requirements were simply quantities remaining in production regions after all real demands had been satisfied from least-cost sources.

As evident from the above applications, the model was most widely used during the 1950's, and its popularity declined somewhat during the 1960's. In recent years, researchers have turned their attention to the development of models with greater flexibility and applicability. The transhipment model was a product of these efforts.

The Transhipment Model

As stated above, the transhipment model is an outgrowth of the old transportation model. The concept of transhipment was first introduced into the transportation problem by Orden in 1956.[10] His formulation allowed any origin or destination to act as an intermediate point in a series of optimum-linked points. The approach focused on the role of nodes in the transportation network, and he used the technique to find the optimum route from one point in a network to another.

A transhipment model was formulated by Kriebel in 1961 that was an extension of the warehouse planning model.[11] He introduced transhipment of a seasonal product where production is maintained at a constant level throughout the year, but demand is seasonal. His problem allowed the shipment of a good from a producing center(s) to consuming centers directly in a given time period or by shipment to a warehouse for transhipment immediately, or for storage for one or more periods before shipment.

King and Logan made the first major application of the model in the field of agricultural economics in 1964.[12] They used an iterative procedure to incorporate economies of scale in processing in a transhipment model to determine the optimum location of processing plants and the shipping patterns of raw material and final product. Using a given set of costs, the authors applied the model to California slaughtering plants to determine whether costs are minimized by processing cattle locally or by sending the livestock to regions with lower processing costs. The processing capacity in any one region was unrestricted in the model.

The King and Logan formulation was a single product model involving inelastic raw product supply and product demand functions. This formulation required subtraction of artificial variables from the optimum shipments once the minimum cost solution was found in order to determine the actual level of shipments. The need for this must be considered an inconvenience when compared with alternative formulations.

In 1965, Hurt and Tramel reformulated the King and Logan problem such that the subtraction of artificial variables was not necessary.[13] They also extended this single product model to include a multiproduct commodity space and multiproduct processing plants processing both final and intermediate products. According to Judge et al., the model proposed by King and Logan is too restrictive for such considerations.[14]

The model presented by Hurt and Tramel was modified and extended by Leath and Martin in 1966.[15] A more general transhipment model was formulated that was capable of solving multifactor, multiproduct, multiregion and multistaged problems of a spatial nature. Multiproduct storage was introduced into the model in addition to the multiproduct processing previously introduced by Hurt and Tramel, and the model considered demands for intermediate as well as final products. Optimum solutions to the Leath-Martin formulation specify least-cost locations for processing and storage. Thus, the efficient location of economic activity is determined rather than assumed. In this multiproduct model, all products compete for the limited storage space and processing facilities of each region, yet product identity is maintained throughout the system. The formulation and solution of a two-product, two-region, five-stage problem was presented. The existence of multiple solutions for transportation problems was also considered, and alternative solutions to the above problem were presented. Methods of incorporating maximum and minimum capacity restraints on supplies, demands, and transportation modes were also presented.

A very important extension of the transhipment model came in 1967 when time-staging was introduced. Leath and Martin extended the multifactor, multiproduct, multiregion, multistaged model discussed above into a time-staged transhipment model capable of considering several time periods simultaneously.[16] This model is particularly useful in studying the flow of a commodity that is produced seasonally but consumed or processed throughout the year. In this framework, a new emphasis is placed on the primary product storage stage of the model since storage provides the link between time periods.

A recent application of a transhipment model was made by Wright.[17] Wright's model involved the stages of acquisition, processing and distribution for one product, and was used to study the impacts of alternate transportation policies on flour mill locations. The model considered 71 wheat supply regions, 28 flour mill locations, 10 ports, and 57 flour markets, and minimum-cost geographical flows were determined.

The above discourse covers the major works in development and application of the transhipment model in agricultural economics. Attention is now directed to the formulation of a model capable of analyzing a multifactor, multiproduct, multiregion, multistaged, and multiperiod problem of the United States grain marketing system (Objective 1).

The Formulation of a Multifactor, Multiproduct, Multiplant Transhipment Model

Many problems in interregional competition are such that consideration of a multicommodity environment in a single model is desirable. This is particularly true in the problem under consideration where grain storage facilities are involved and several grains compete for the limited storage space. The model formulated for this study is basically the Leath and Martin formulation discussed above under transhipment models. However, modifications have been necessary to meet the needs of this study as well as meet the demands of available computing software. This model will be illustrated using examples in the following section. Once the formulation of a single period model has been presented, a multiple period model will be introduced.

A Formulation Involving One Time Period

To illustrate the transhipment model developed for this study, a hypothetical two-product spatial equilibrium problem related to grain marketing and distribution will be presented. The stages of assembly, inventories, acquisition, processing, and distribution are considered for each product in a two-region problem. As products flow through the system, each competes for the limited capacities in storage and processing yet product identity is maintained throughout the various stages. Considered in the hypothetical example are:

(1) two primary production regions,

(2) two primary products -- hard wheat and soft wheat,

(3) two storage facilities (regions) with total capacity available to each grain,

(4) two processing facilities (regions) with hard wheat and soft wheat milling capacity,

(5) two regions demanding quantities of each grain, and

(6) two regions demanding particular proportions of the processed products of each grain (flour demands).

The general matrix format for this example is presented in Figure 5. To facilitate the discussion, the large matrix is subdivided into submatrices, and the relevant ones have been given letter designations. The problem is formulated such that each grain moves from farm to storage facilities (Submatrix A). Once the grain is received at storage facilities, it may be shipped to the milling sector (Submatrix D), may be shipped out to satisfy the wheat demands (Submatrix E), or may enter storage (Submatrix C) if not needed to satisfy whole grain or milling demands. Storage charges are incurred by quantities entering storage. Grain that enters the milling sector is milled and the flour shipped out to satisfy flour demands (Submatrix I).

The processing capacity of each area is allocated to processing of each grain in the same ratio as exists in the total final demands for flour. Allocating the capacity in this manner insures that processing capacity is not exceeded in each milling area and permits flexibility in the actual quantity of each grain processed in each area since the

Activity	Grain Storage		Grain Processing	Grain Demands	Flour Demands	Carry-over	
Product Region	HW HW SW SW 1 2 1 2	-- -- 1 2	HW HW SW SW 1 2 1 2	HW HW SW SW 1 2 1 2	HW HW SW SW 1 2 1 2	-- --	S_i
(Production) Product Region HW 1 HW 2 SW 1 SW 2	Whole Grain Shipments to Storage		Quantities Entering Storage				Grain Production By Region
(Storage) Product Region HW 1 HW 2 SW 1 SW 2	B Excess Receiving Capacity in Storage Regions	C	D Whole Grain Shipments to Flour Mills	E Whole Grain Shipments to Deficit Regions	Ending Inventories		Storage Capacity By Region
-- 1 -- 2		F				G	
(Processing) Product Region HW 1 HW 2 SW 1 SW 2	Excess Storage Capacity By Region		H Excess Milling Capacity		I Flour Shipments from Flour Mills		Milling Capacity By Region
R_j	Storage Capacity		Milling Capacity	Quantities Demanded	Quantities Demanded	Carry-over	

Figure 5. Matrix Format of a Two-Product Transhipment Problem

restriction does not require the volume processed to be exactly equal to the total processing capacity.

The matrix of costs, supplies, capacities and demands are presented in Figure 6. Costs used in the problem may be interpreted as follows:

Submatrix A: Costs include transit to storage facilities from areas of production plus in-handling costs at elevators by type of grain.

Submatrices B, F, and H: Zeros are entered on the main diagonal. Shipments over these "routes" represent unused capacities in receiving, storage, and milling, respectively, and it is assumed that no charges are incurred when capacity goes unused.

Submatrix C: Costs are storage charges per unit by area and type of grain for quantities carried in inventory for a full period.

Submatrix D: Costs include out-handling charges at storage facilities plus transit charges plus in-handling charges at flour mills.

Submatrix E: Costs include out-handling charges at storage facilities plus transit to wheat demand centers by type of grain.

Submatrix G: Zeros are entered in both cells. Shipments over these routes are dummy shipments to the dummy demand and are equal to the total grain inventories by area. These inventories incur storage charges in Submatrix C.

Activity		Grain Storage						Grain Processing				Grain Demands				Flour Demands				Carry-over		
Product		HW	HW	SW	SW	--	--	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	--	S_i	i
Region		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	--		
(Production)					A																	
Product	Region																					
HW	1	4	8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	40	1
HW	2	9	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	60	2
SW	1	*	*	4	8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	70	3
SW	2	*	*	9	5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	20	4
(Storage)																						
Product	Region				B		C				D				E							
HW	1	0	*	*	*	12	*	18	21	*	*	4	7	*	*	*	*	*	*	*	40	5
HW	2	*	0	*	*	*	10	22	19	*	*	8	5	*	*	*	*	*	*	*	60	6
SW	1	*	*	0	*	12	*	*	*	18	21	*	*	4	7	*	*	*	*	*	40	7
SW	2	*	*	*	0	*	10	*	*	22	19	*	*	8	5	*	*	*	*	*	60	8
							F													G		
--	1	*	*	*	*	0	*	*	*	*	*	*	*	*	*	*	*	*	*	0	40	9
--	2	*	*	*	*	*	0	*	*	*	*	*	*	*	*	*	*	*	*	0	60	10
(Processing)																						
Product	Region										H								I			
HW	1	*	*	*	*	*	*	0	*	*	*	*	*	*	*	12	16	*	*	*	40	11
HW	2	*	*	*	*	*	*	*	0	*	*	*	*	*	*	17	13	*	*	*	30	12
SW	1	*	*	*	*	*	*	*	*	0	*	*	*	*	*	*	*	12	16	*	20	13
SW	2	*	*	*	*	*	*	*	*	*	0	*	*	*	*	*	*	17	13	*	15	14
R_j		40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	60		
j		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		

*Denotes that cost coefficients are sufficiently high to prevent entry in an optimal solution.

Figure 6. Matrix of Costs, Supplies, Capacities, and Demands for a Two-Product Transhipment Problem

Submatrix I: Costs include milling costs plus out-handling charges for flour at mills plus transit to flour demand centers. The results would be the same if milling costs were included in Submatrix D.

The routes containing *'s are infeasible routes and have an associated cost coefficient sufficiently high to preclude entry in the minimum-cost solution.

The capacities, supplies, and requirements are given in the S_i column and R_j row at the lower and right-hand margins of Figure 6. Storage capacities for regions (plants) 1 and 2 are 40 and 60 units, respectively. The total capacity of each region is made available to each grain with respect to grain receiving activities. Thus, the grain receiving capacity of each storage region is twice the actual storage capacity. However, both grains compete for the limited storage space, and the volume stored in each region cannot exceed capacity. Milling capacity is specified by type of grain in each region. Note that capacities are introduced into the model as supplies and demands.

A requirement of this model is that total supply must equal total demand (Equation 4). In the problem under consideration, supply exceeds requirements by 60 units; therefore, the requirements at the dummy demand (R_{19}) is set at 60 units. This is the actual carryover of wheat in this example. The unit of measure must be standardized throughout the problem. Hence, the flour demands are expressed in wheat equivalents.

Given the information in Figure 6, the next step is to find a combination of shipments (set of X_{ij}'s) that will minimize total cost

(Equation 1) and satisfy the four restrictions specified in Equations (2) through (5). At least one solution can be found, and several solutions satisfying these equations may exist.

The shipment matrix for a minimum-cost solution is presented in Figure 7. No other shipment pattern exists that will result in a lower total cost, but there may be other solutions yielding the same total cost. In this discussion, a letter followed by subscripts will be used when reference is made to a particular cell of a particular Submatrix. For example, A_{23} refers to the cell in the second row and third column of Submatrix A.

Entries in Submatrix A represent the initial movement of grain from production regions to storage facilities. This is the optimal assembly pattern for this problem. For example, the volume of wheat received by storage region 1 is 80 units -- 40 units of hard wheat ($A_{11} + A_{21}$) and 40 units of soft wheat ($A_{33} + A_{43}$). Excess receiving capacity by region and type of wheat at storage plants is represented by entries in Submatrix B, assuming that receiving capacity for each wheat is equal to storage capacity. In region 1, receiving capacity for both grains is completely utilized ($B_{11} = 0$ and $B_{33} = 0$).

Once the grains are received in the storage facilities, there are three possible dispositions for this grain: (1) it may move to flour mills for milling through Submatrix D; (2) it may be shipped to satisfy wheat demands through Submatrix E; or (3) if not needed to satisfy milling and wheat demands, it moves into storage through Submatrix C and incurs storage charges. To demonstrate the logic of this, consider what happens to the 40 units of hard wheat received in storage region 1. Twenty-five units are shipped to hard wheat mills in region 1 (D_{11}),

Activity		Grain Storage						Grain Processing				Grain Demands				Flour Demands				Carry-over		
	Product	HW	HW	SW	SW	--	--	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	--	S_i	i
	Region	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	--		
(Production)																						
Product	Region				A																	
HW	1	40	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	1
HW	2	0	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	2
SW	1	.	.	40	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	3
SW	2	.	.	0	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	4
(Storage)																						
Product	Region				B		C				D				E							
HW	1	0	.	.	.	0	.	25	0	.	.	15	0	.	.	.	.	.	.	.	40	5
HW	2	.	0	.	.	.	25	5	20	.	.	0	10	.	.	.	.	.	.	.	60	6
SW	1	.	.	0	.	20	.	.	.	15	0	.	.	5	0	.	.	.	.	.	40	7
SW	2	.	.	.	10	.	15	.	.	0	10	.	.	0	25	.	.	.	.	.	60	8
							F													G		
--	1	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	20	40	9
--	2	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	40	60	10
(Processing)																						
Product	Region										H								I			
HW	1	.	.	.	.	.	.	10	.	.	.	.	.	.	.	30	0	.	.	.	40	11
HW	2	.	.	.	.	.	.	.	10	.	.	.	.	.	.	0	20	.	.	.	30	12
SW	1	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	15	0	.	20	13
SW	2	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	0	10	.	15	14
R_j		40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	60		
j		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		

Figure 7. Matrix of shipments for a Two-Product Transhipment Problem

15 units are shipped to satisfy hard wheat requirements in region 1 (E_{11}), and 0 units are stored (C_{11}).

The grain inventories in storage at the end of the period may be found in Submatrix C by region and type of wheat. The volume stored in region 1 is 20 units -- 0 units of hard wheat (C_{11}) and 20 units of soft wheat (C_{31}). Likewise, the volume stored in region 2 is 40 units ($C_{22} + C_{42} = 25 + 15$). The total excess storage capacity by region is represented by entries in Submatrix F, and shipments to the dummy demand (Submatrix G) are equivalent to the total ending inventories by region but not by type of wheat. For example, the 40 units ending inventory in region 2 (G_{21}) is composed of 25 units of hard wheat (C_{22}) and 15 units of soft wheat (C_{42}).

One stage of the model remains to be considered. This is the processing (flour milling) stage. As noted above, shipments of wheat to flour mills are represented by entires in Submatrix D. Once wheat is received at mills, it is processed and shipped out to satisfy flour demands. Entries in Submatrix I represent flour shipments from the milling sector by region and type of flour. To see the logic of this, consider the 25 units of hard wheat shipped from storage region 1 to the hard-wheat mill in region 1 (D_{11}). The distribution of flour milled from this 25 units of hard wheat along with any hard wheat procured from storage region 2 by milling region 1 (5 units in this example) is found in row one of Submatrix I. Flour consuming regions 1 and 2 receive 30 and 0 units of this flour, respectively. Since the hard-wheat milling capacity of region 1 is 40 units and 30 units were milled, 10 units of excess capacity exist, and this is represented by entry H_{11} of Submatrix H. The activities of procurement, distribution, and capacity utilization for soft-wheat milling in region 1 may be determined in a similar fashion.

It should be noted that in the above formulation, product identity is maintained throughout the network. This is a very desirable feature in that many research problems in interregional competition involve more than one product at the assembly and/or distribution stages.

The Existence of Multiple Solutions

The attainment of an optimum solution to a specific transportation problem does not necessarily imply that the solution is unique. As stated before, more than one optimal solution may exist for a given problem. In multistage transhipment problems, the frequency of multiple solutions generally increases as the number of stages under consideration increases. For a discussion of the number of alternate solutions that may be derived once the existence of two or more optimal solutions has been established, see Loomba.[18]

Alternate optimal solutions exist for the above problem. The same total cost would result if the shipment pattern of Figure 7 were altered to allow the hard-wheat milling facility of region 1 to procure all 30 units of the hard wheat milled from storage region 1. Now only 10 units of hard wheat would be available at the storage facility in region 1 to satisfy the demand for hard wheat in region 1 (R_{11}), and 5 units of the 15 units required would have to be shipped in from storage region 2 (route E_{21}).

The above alteration in the least-cost shipping pattern will not change the total cost for the system; however, it does affect the distribution of the total cost among segments or stages. The change will result in a decrease of 20 units in the transportation costs associated with shipments between storage facilities and processing facilities, and the transportation costs associated with satisfying the whole grain demands will be increased by 20 units. Assuming that the problem represents the grain marketing system, the fact that multiple solutions do exist means that the minimum-cost shipment pattern for the system will not, in general, yield a minimum-cost shipping pattern for each individual segment or industry making up the system. Thus, various segments may have very real preferences for a particular solution among that set of solutions which are optimal for the entire system. The bargaining power of individual segments in computing for available supplies may be important in determining which shipment pattern is most likely to exist in the real world.

A Formulation Involving Multiple Time Periods

Many research problems can be more accurately analyzed if a multiperiod model is employed. This is certainly true in studying the grain marketing system because production is highly seasonal and requirements for commercial storage are not uniform throughout the marketing year. To illustrate a method of simultaneously considering several time periods with the transhipment model, the problem considered above will be extended to include two successive periods of time.

The matrix of costs, supplies, capacities, and demands which are used in this simplified, hypothetical problem is presented in Figure 8. It should be noted that costs, demands, and capacities are identical for both time periods. However, production was reduced in both areas during the second time period. Costs used in the problem may be interpreted

Period			I																		II																				
	Activity		Grain Storage						Grain Processing				Grain Demands				Flour Demands				Grain Storage						Grain Processing				Grain Demands								Carry-over		
	Product		HW	HW	SW	SW	--	--	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	--	--	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW		S_i	i
		Region	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2			
	(Production)				[a]	A																																			
	HW	1	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	1
	HW	2	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	2
	SW	1	.	.	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	3
	SW	2	.	.	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	4
	(Storage)					B		C				D				E								F																	
	HW	1	0	.	.	.	12	.	18	21	.	.	4	8	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	5
	HW	2	.	0	.	.	.	10	22	19	.	.	7	5	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	6
I	SW	1	.	.	0	.	12	.	.	.	18	21	.	.	4	8	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	7
	SW	2	.	.	.	0	.	10	.	.	22	19	.	.	7	5	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	8
								G																		H															
	--	1	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	9
	--	2	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	60	10
	(Processing)											I								J																					
	HW	1	.	.	.	.	.	.	0	.	.	.	.	.	.	.	12	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	11
	HW	2	.	.	.	.	.	.	.	0	.	.	.	.	.	.	17	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	12
	SW	1	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	12	16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	13
	SW	2	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	17	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	14
	(Production)																							K																	
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	15
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	16
	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	17
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	9	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	18
	(Storage)																							L		M				N				O							
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	6	.	18	21	.	.	4	8	.	.	.	.	.	.	.	40	19
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	5	22	19	.	.	7	5	.	.	.	.	.	.	.	60	20
II	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	6	.	.	.	18	21	.	.	4	8	.	.	.	.	.	40	21
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	5	.	.	22	19	.	.	7	5	.	.	.	.	.	60	22
																										P													Q		
	--	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	0	40	23
	--	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	0	60	24
	(Processing)																													T								U			
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	12	16	.	.	.	40	25
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	17	13	.	.	.	30	26
	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	12	16	.	20	27
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	17	13	.	15	28
	R_j		40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	60		
	j		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		

[a]Cells containing dots have cost coefficients sufficiently high to prevent entry in an optimal solution.

Figure 8. Matrix of Costs, Supplies, Capacities, and Demands for a Two-Product, Time-Staged Transhipment Problem

as follows:

Submatrices A and K: Costs include transit to storage areas from area of production plus "in-handling" costs by type of grain.

Submatrices B, G, H, I, L, P, and T: Zeros are entered on main diagonals. Shipments made over routes in B, I, L, and T represent unused capacities in storage and processing and it is assumed that no costs are incurred when capacity goes unused. A cost could be assigned to excess capacity if desired. Shipments made over routes in G, H, and P are dummy shipments and serve only as accounting entries in the model. Hence, no costs are incurred.

Submatrix C: Costs include all storage charges for two full time periods by area and type of grain.

Submatrices F and M: Costs include all storage charges for one full time period by area and type of grain.

Submatrices D and N: Costs include "out-handling" costs at storage facility plus transit charges from storage to milling facility plus "in-handling" costs at milling facility plus processing costs by type of wheat and area.

Submatrices E and O: Costs include out-handling costs at storage facility plus transit to feeding demand areas by type of grain.

Submatrix Q: Zeros are entered in both cells.

Submatrices J and U: Costs include out-handling costs at milling facility plus transit to flour demand centers.

The C_{ij} cells containing dots (.) represent an infinite cost to prevent entry of these "routes" into the optimal shipment pattern.

The shipment matrix for a minimum cost solution is presented in Figure 9. The initial movement of whole grain from the production regions is to storage facilities. Entries in submatrices A and K represent these shipments by type of grain.* For example, 60 units of hard wheat moved from production region 2 to storage region 2 in time period I; this movement is depicted by the entry in cell A_{22} of Figure 9. Note that the total storage capacities of 40 and 60 units in storage regions I and II, respectively, are made available to each grain. Consequently, the maximum quantity that a storage region may receive in one time period is twice the capacity. Excess receiving capacity by type of grain for each storage area is represented by entries in submatrices E and L. These entries are dummy shipments and no costs are incurred.

Entries in submatrices E and O represent quantities of each grain shipped to satisfy whole grain demands for feeding. Once the demands for whole grain have been satisfied, the remaining quantities of grain may remain in storage or may be shipped out to flour mills for processing. Grain moving through storage facilities to milling facilities in period I does not incur storage costs. These shipments by area and type of grain are represented by entries in submatrix D. Grain moving from storage facilities to milling facilities in period II is represented by entries in submatrix N. If these quantities are produced in

*When reference is made to two submatrices together, the two submatrices will refer to time periods I and II, respectively.

Period			I																		II																				
	Activity		Grain Storage						Grain Processing				Grain Demands				Flour Demands				Grain Storage						Grain Processing				Grain Demands				Flour Demands				Carry-over		
	Product		HW	HW	SW	SW	—	—	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	—	—	HW	HW	SW	SW	HW	HW	SW	SW	HW	HW	SW	SW	—		
		Region	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	--	s_i	i
I	(Production)					A																																			
	HW	1	40	0	.[a]	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	1
	HW	2	0	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	2
	SW	1	.	.	40	30	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	70	3
	SW	2	.	.	0	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	4
	(Storage)					B		C				D				E								F																	
	HW	1	0	.	.	.	0	.	30	0	.	.	10	0	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	5
	HW	2	.	0	.	.	.	25	0	20	.	.	5	10	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	6
	SW	1	.	.	0	.	20	.	.	.	15	0	.	.	5	0	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	7
	SW	2	.	.	.	0	.	0	.	.	0	10	.	.	0	25	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	60	8
								G																		H															
	—	1	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	9
	—	2	.	.	.	.	.	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	.	.	.	.	.	.	.	.	.	.	.	.	60	10
	(Processing)											I								J																					
	HW	1	.	.	.	.	.	.	10	.	.	.	.	.	.	.	30	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	40	11
	HW	2	.	.	.	.	.	.	.	10	.	.	.	.	.	.	0	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	12
	SW	1	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	15	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	13
	SW	2	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	0	10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	14
II	(Production)																							K																	
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	15
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	50	16
	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	17
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	18
	(Storage)																							L		M				N				O							
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	0	.	30	0	.	.	0	0	.	.	.	.	.	.	.	40	19
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	5	0	20	.	.	15	10	.	.	.	.	.	.	.	60	20
	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	10	.	.	.	15	0	.	.	5	0	.	.	.	.	.	40	21
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25	.	0	.	.	0	10	.	.	0	25	.	.	.	.	.	60	22
																										P													Q		
	—	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	.	.	.	.	.	.	30	40	23
	—	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	30	.	.	.	.	.	.	.	.	.	.	.	.	30	60	24
	(Processing)																													T								U			
	HW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	.	30	0	.	.	.	40	25
	HW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10	.	.	.	.	.	.	0	20	.	.	.	30	26
	SW	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	15	0	.	20	27
	SW	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	0	10	.	15	28
		R_j	40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	40	60	40	60	40	60	40	30	20	15	15	10	5	25	30	20	15	10	60		
		j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		

[a]Cells containing dots were not in the optimal solution because costs were sufficiently high to prevent entry.

Figure 9. Matrix of Shipments for a Two-Product, Time-Staged Transhipment Problem

period II, no storage charges are incurred as the grain only moves through the storage facilities. However, should this be grain produced in period I, storage costs will be incurred for one time period. The method in which the storage costs are incurred is discussed later. Excess processing capacity is represented by entries in submatrices I and T by area and type of grain. These are dummy shipments and no costs are incurred. For example, excess capacity in period I is determined for each area by summing alternate entries on the main diagonal in I. Thus, the excess capacity is 15 units in both milling areas. Entries in submatrices J and U represent shipments of the processed products from flour mills to flour demand areas. In this formulation, no provisions are made for flour storage. Consequently, the quantities of grain received in each processing region through submatrices D and N are identical to the quantities of flour shipped from each processing region through submatrices J and U.

Quantities of grain that are produced in excess of whole grain and flour demands remain in storage, and storage charges are incurred. The quantities of grain moving into storage are represented by entries in submatrices C, F, and M. Entries in submatrix C incur storage costs for two time periods. Thus, the 25 units of hard wheat (the shipment through route C_{22}) enter storage for two complete time periods, and these units are not available for shipment in the second time period. Alternatively, quantities produced in period I may move into storage through routes located on the main diagonal of submatrix F; in this case, storage charges are incurred for the first time period only. Consequently, these quantities as well as quantities shipped in from areas of production in the second time period (submatrix K) are available to meet various demands in period II. Thus, the quantities available at the storage facilities for shipment in period II are as follows: hard wheat in storage area 1 is 30 units ($K_{11} + K_{21} + F_{11} = 30 + 0 + 0 = 30$ units); hard wheat in storage area 2 is 50 units ($K_{12} + K_{22} + F_{22} = 0 + 50 + 0 = 50$ units); soft wheat available in storage area 1 is 30 units ($K_{33} + K_{43} + F_{33} = 30 + 0 + 0 = 30$ units); and soft wheat in storage area 2 is 35 units ($K_{34} + K_{44} + F_{44} = 20 + 0 + 15 = 35$ units).

After the feeding and processing demands for grain have been satisfied in period II, the remaining quantities of grain located at the storage facility move into storage and incur storage charges during the second time period. These quantities are represented by entries in submatrix M. Thus, 5 units of hard wheat (M_{22}) move into storage in area 2, and 10 units of soft wheat (M_{31}) move into storage in area 1. These entries do not represent total storage in period II since entries in submatrix C remain in storage for two complete time periods.

The quantities of grain stored by area and type of grain for each time period are determined from the shipment matrix presented in Figure 9. During period I, the volume stored in area 1 is 0 units of hard wheat ($C_{11} + F_{11}$) plus 20 units of soft wheat ($C_{31} + F_{33}$) or 20 units. The volume stored in area 2 is 25 units of hard wheat ($C_{22} + F_{22}$) plus 15 units of soft wheat ($C_{42} + F_{44}$) or 40 units. Thus, total volume moving into storage and incurring storage costs in the first time period is 60 units. This quantity may be verified by subtracting total final demands in period I from total production during this period. Likewise, for period II, volume stored in area 1 is 0 units of hard wheat ($C_{11} + M_{11}$) plus 30 units of soft wheat ($C_{31} + M_{31}$) or 30 units, and volume stored in area 2 is 30 units of hard wheat ($C_{22} + M_{22}$) plus 0 units of soft wheat ($C_{42} + M_{42}$) or 30 units. Thus, total volume stored in period II is 60 units. These ending inventories also appear in submatrix Q by area but not by type of grain (area 1 = Q_{11} = 30 units and area 2 = Q_{21} = 30 units).

Entries in submatrices G, H, and P are dummy shipments, and no costs are incurred. Even though these entries are only accounting entries in the model, interpretation reveals useful information related to the storage facilities. Since entries in submatrix C represent quantities of grain produced in period I and stored for two full time periods, entries in submatrix G represent the excess storage space available in period I by area, after the space used by quantities in C has been accounted for. Entries in submatrix H represent the quantities of grain moving into storage for two full periods through routes in C at the beginning of the first period. Consequently, this storage capacity is no longer available for storage of grain produced in period II. These quantities in H appear by area but not by type of grain; hence, $H_{11} = C_{11} + C_{31}$ and $H_{22} = C_{22} + C_{42}$. Since shipments over routes in submatrix Q to the slack or dummy demand represent the ending inventories in storage during the last period, the entries in submatrix P represent the unused storage capacity in each storage area during this period.

In this formulation, it is possible for the volume stored to exceed storage capacity in any area during the first time period. This will happen if a storage area is filled by entries in submatrix C (these quantities incur storage costs for two full periods) and additional quantities, which incur storage costs for the first period, are shipped to the area through submatrix F. Should this happen, it will be corrected in period II because storage in a particular region will not exceed capacity unless R_{37} is greater than total storage capacity, and the quantities stored in excess of capacity will be forced out of storage. In this situation where the maximum restraint on storage is violated, the accounting of the model is still correct because all units in excess of capacity incur storage costs.

This may appear at first to be a major weakness of the model since it is possible to violate storage capacity restraints, but this can actually be a very realistic feature. Many elevator operators may actually store excess grain on the ground or in temporary facilities during the peak harvest season until storage space becomes available in the regular facilities or until the grain can be sold. In one respect, this is a useful feature of the model because it is possible to determine what areas need additional storage facilities and the amount needed. Likewise, if the storage capacity of any area is consistently underutilized, this might suggest a need to reduce the available storage capacity in the area.

The problem of degeneracy is much more likely to occur in multistage transportation models involving multiple periods of time than in the conventional single-stage model. Multistage problems must be formulated with care to insure that the supplies available for shipment over permitted routes are adequate to satisfy the given demands, since shipments over non-permissible routes (routes containing an infinite cost coefficient) will yield an infeasible solution.

Modifications of the Model

The researcher can make several modifications in the model presented in Figure 8. A few of these modifications are mentioned in the hope of stimulating further thought in this area.

A very useful modification is that of a minimum capacity restraint to insure that a minimum percentage of storage capacity will be utilized in each storage region. This type of restraint might be desirable when government policy is aimed at maintaining grain storage at a specified minimum percentage of capacity in the respective regions. A technique of introducing such a restraint is illustrated elsewhere.[19]

Other restraints which may be included in the time-staged transportation model are: (1) restrictions on the total quantity that may be shipped from a specified group of supply points, (2) minimum and maximum restraints on a particular supply or demand area, and (3) restrictions on the quantity of a commodity that can be shipped at a given transportation rate where alternative modes of transportation are available. The third restriction is useful where only a limited quantity may be shipped at a particular rate.

If transit rates are a characteristic of the problem, restrictions on quantities received at demand areas by various modes of transportation may be imposed in the formulation of a problem. The introduction of transit rates into the transportation model is illustrated in a study by Uhrig.[20]

Additional time periods can be included in the model presented in Figures 8 and 9. Expansion to four time periods, for example, would involve duplicating the supplies and demands with the appropriate S_i and R_j quantities, and a change in the cost coefficients in the submatrix corresponding to submatrix C (Figure 8) to include all storage charges for four time periods. Likewise, the submatrix corresponding to submatrix M would represent storage charges for three periods, and cost coefficients in the corresponding submatrices for periods III and IV would be for two periods and one period of storage.

The National Model

The two formulations of the transhipment model presented in Figures 6 and 8 were expanded to a national scale to analyze the United States grain marketing industry. Due to data processing considerations, the revised simplex technique of linear programming was used rather than a transportation algorithm to generate solutions to specific problems. The two basic weaknesses of the transportation formulation were eliminated by using linear programming techniques. First, in the hypothetical problems presented, flour milling capacity had to be allocated between hard wheat and soft wheat in some manner. Formulated in a linear programming framework, total regional processing capacity can be made available to each grain, and the type of grain processed is determined within the model. Second, it was possible for the volume stored in a given region to exceed storage capacity in all periods except the last one in a multiproduct, multiperiod transportation problem. The storage capacity restraints cannot be violated when such a problem is solved as a linear programming problem.

The linear programming formulation of the transhipment model employed in this study included the following:

(1) five primary products -- hard wheat, soft wheat, durum wheat, feed grain and soybeans,

(2) forty-two domestic regions with associated production, commercial storage, and flour milling activities,

(3) thirteen export regions, and

(4) flour and grain demands associated with each domestic and export region.

Mathematical Definition of the Model

The mathematical definition of the LP transhipment model may be stated as follows:

$$\text{Minimize } Z = \sum_k \sum_i \sum_j \sum_t C_{kij} \; T^t_{kij} + \sum_k \sum_i \sum_j \sum_t C_{kij} \; XG^t_{kij} \tag{6}$$

$$+ \sum_k \sum_i \sum_j \sum_t C_{kij} \; XM^t_{kij} + \sum_k \sum_j \sum_i \sum_t C_{kij} \; XF^t_{kji}$$

$$+ \sum_k \sum_j \sum_t C_{k \cdot j} \; QM^t_{k \cdot j} + \sum_k \sum_i \sum_t C_{ki\cdot} \; I^t_{ki\cdot}$$

subject to the constraints,

$$S^t_{ki} + I^{t-1}_{ki\cdot} + \sum_i T^t_{kij} = \sum_j T^t_{kij} + \sum_j XG^t_{kij} + \sum_j XM^t_{kij} + I^t_{ki\cdot} \tag{7}$$

$$DG^t_{kj} = \sum_i XG^t_{kij} \tag{8}$$

$$SCAP_i \geq \sum_k I^t_{ki\cdot} \tag{9}$$

$$MCAP^t_j \geq \sum_k QM^t_{k\cdot j} \tag{10}$$

$$QM^t_{k\cdot j} = \sum_i XM^t_{kij} = \sum_i XF^t_{kji} \tag{11}$$

$$DF^t_{ki} = \sum_j XF^t_{kji} \tag{12}$$

where:

Z is the cost of the industry,

t is the time period (t = 1, 2, 3, 4),

C_{kij} is the cost of transferring a unit of product from location i to location j,

$C_{k\cdot j}$ is the cost of milling a unit of product k in region j,

$C_{ki\cdot}$ is the cost of storing a unit of product k in region i,

T^t_{kij} is the quantity of product k transhipped from supply region i to region j,

XG^t_{kij} is the quantity of product k shipped from supply region i to satisfy grain demands in region j,

XM^t_{kij} is the quantity of product k shipped from supply region i to milling facilities in region j,

XF^t_{kji} is the quantity of the k^{th} type of flour shipped from processing facilities of region j to satisfy flour demands in region i,

$QM^t_{k\cdot j}$ is the quantity of product k milled in region j,

$I^t_{ki\cdot}$ is the quantity of product k stored in region i,

S^t_{ki} is the off-farm sales of product k in region i,

DG^t_{kj} is the demand for product k in region j,

$SCAP_i$ is the storage capacity in region i,

$MCAP^t_j$ is the milling capacity in region j, and

DF^t_{ki} is the demand for the k^{th} type of flour in region i.

Equation (6) is the total cost function for the grain marketing industry and the objective is to minimize the total cost of marketing. Equation (7) states that for a particular product, off-farm sales in a given region plus carryover from the previous period (t - 1) plus any transhipments into that region must equal all out-shipments from that region plus the ending inventory in time period t. Equation (8) is the constraint requiring that shipments into a particular region to satisfy grain demands must be equal to requirements in that region. Equations (9) and (10) are capacity constraints that limit storage and processing in a particular region to the available capacities. Since no provisions are made for flour storage, Equation (11) states that the quantity milled of a particular product in a given region is identical with in-shipments of wheat to that region and out-shipments of flour from that region. Equation (12) requires that flour receipts in a region equal the flour demand of that region by type of flour.

Assumptions of the Model

Any economic model must, of necessity, be a simplification of the real world. Hence, the researcher must make certain restrictive assumptions to reduce the model to a manageable size. The following selective assumptions were made:

(1) Regional production and consumption are assumed to take place at particular points in each region, and quantities supplied and demanded are preassigned.

(2) Transfer charges between regions include loading costs at origin and receiving costs at destination, and the per unit charge between two regions is independent of the number of units moved.

(3) Only that quantity of wheat required to meet the domestic and export demands for flour moves through

the processing sector.

(4) Feed grains are perfect substitutes, and domestic and export requirements are met by "least-cost" type of grain.

(5) Feed milling is decentralized and occurs at points of consumption which eliminates the necessity of including a feed milling sector in the model.

(6) Soybean crushing plants represent the final domestic demand for soybeans.

(7) The domestic demand for durum wheat for processing is specified at the location of durum product mills, and the distribution of the semolina flour is excluded from the model.

Given the methodological framework presented in this chapter, the next step is to implement this model with basic data. The following chapter will be devoted to that end.

FOOTNOTES

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CHAPTER IV

BASIC DATA

The basic data for this study were obtained from various secondary sources. Though no surveys were conducted for the purposes of data collection, data from some of the sources are based on survey results. Secondary data were used for two reasons. First, a major objective of the study was methodological in nature. Second, the vast amount of data required for a national model involving several grains prohibited the generation of data specifically tailored to the requirements of the model.

Regional Demarcation

The area under investigation is the United States excluding Alaska and Hawaii. The partitioning of the United States into various subregions involves many subjective considerations as well as the availability of disaggregated data. The transportation rate structure must be given consideration in fixing regional boundaries, and dimensional limits in data processing place a restriction upon the number of regions that can be considered.

States are the smallest geographic area for which much of the required data are available. Consequently, all regions except 12 were composed of one or more states. In these exceptions, transportation rate considerations made it desirable to subdivide six states into two or more regions. For example, in the case of Illinois, an entirely different rail rate structure exists for the northern and southern sections of the state. Relevant rail rates on grain moving south are for shipments originating in southern Illinois. On the other hand, the relevant rail rates on grain moving east are for shipments originating in northern Illinois. A similar situation exists for other states that were divided.

In this study the continental United States was divided into 42 regions. The same regional demarcation applies to production, storage, processing, and consumption of each grain and grain product. These 42 regions are depicted in Figure 10. In addition, 13 demand points were designated as ports of exit for U.S. grain exports. A separate specification of points representing export demands is desirable because special transportation rates are available for grain moving to the various ports by rail, and these rates are considerably lower than domestic rates. The various export points and ports included in each are shown in Figure 11. These port groupings were used to consolidate export data for the various grains and grain products. The regional code numbers presented in Figures 10 and 11 will be used throughout this chapter to facilitate presentation of regional data.

Regional production and consumption were assumed to take place at particular origin and destination points in each region, and quantities available and requirements were preassigned. Separate points for production and consumption were specified for each region. Such a procedure should introduce more realism since regional concentrations of production and consumption do not generally coincide. The selection of points representing grain origins was based on two criteria:

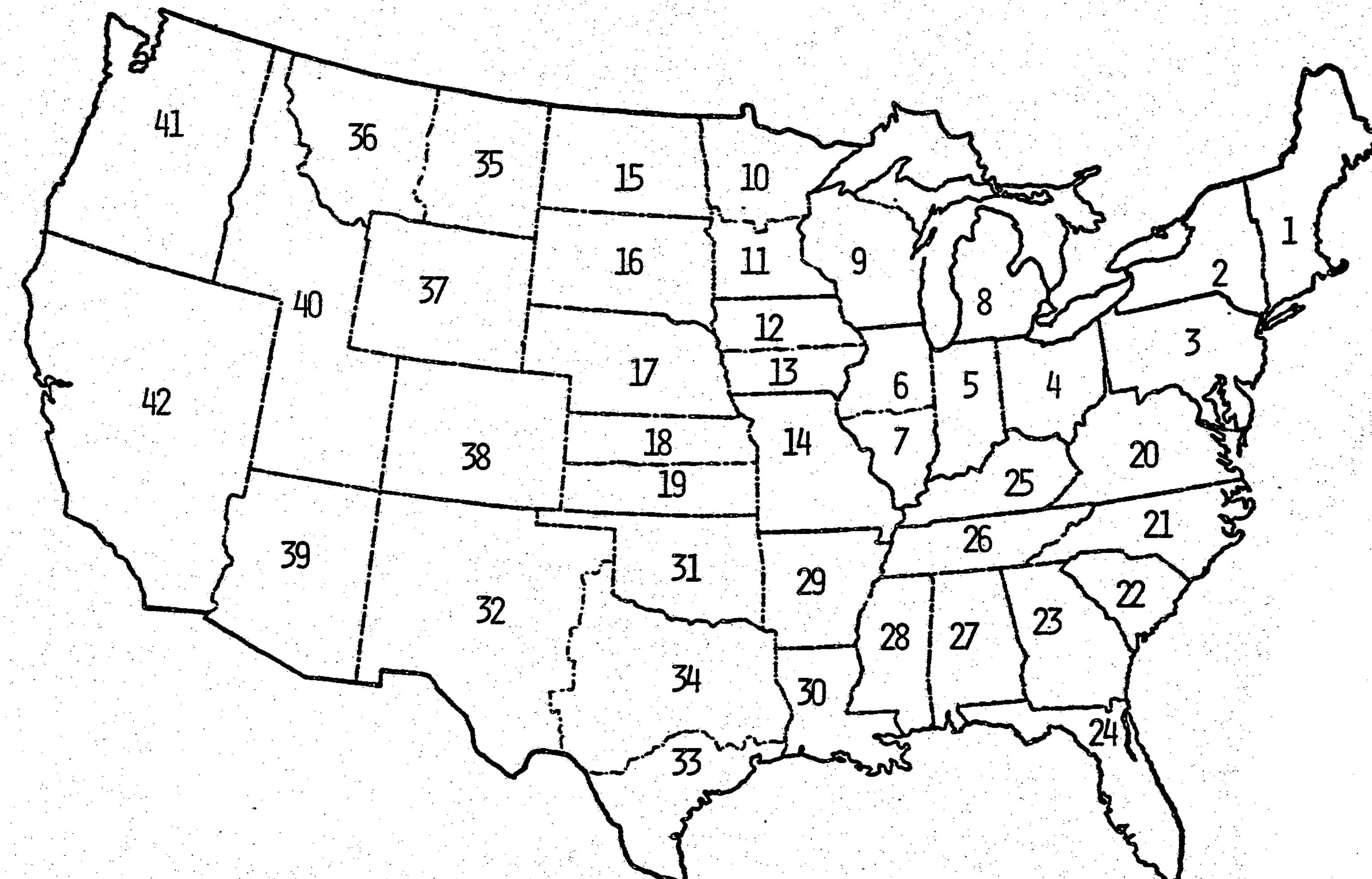
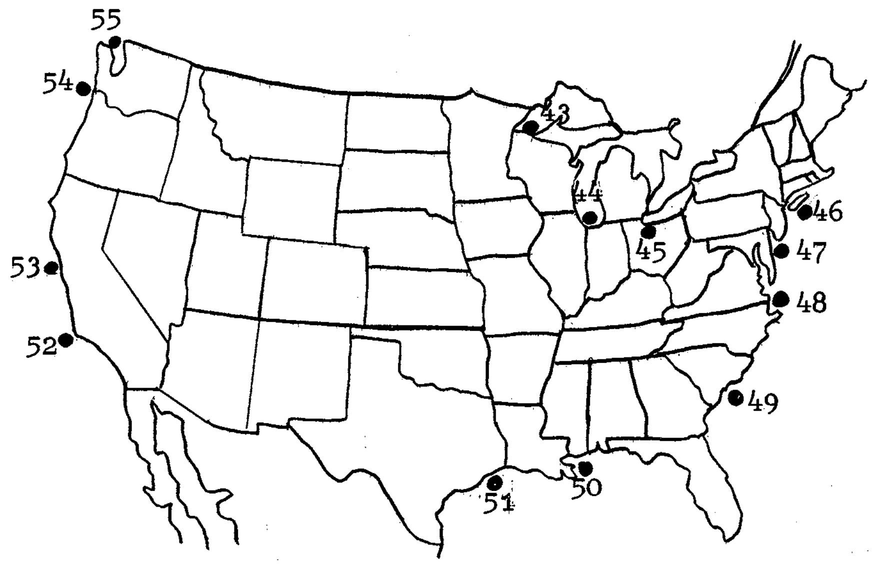


Figure 10. Regional Demarcation of the United States



LAKE PORTS

43 - Superior, Wisc.
Duluth, Minn.

44 - Chicago, Illinois
Milwaukee, Wisc.

45 - Toledo, Ohio
Saginaw, Mich.
Carrollton, Mich.
Zilwaukee, Mich.
Buffalo, N. Y.

ATLANTIC PORTS

46 - Albany, N. Y.
Boston, Mass.
Portland, Me.

47 - Baltimore, Md.
Philadelphia, Pa.
New York, N. Y.

48 - Norfolk, Va.

49 - N. Charleston, S. C.

GULF PORTS

50 - New Orleans, La.
Mobile, Ala.
Pascagoula, Miss.
Port Allen, La.
Destrehan, La.

51 - Houston, Tex.
Port Arthur, Tex.
Beaumont, Tex.
Galveston, Tex.
Corpus Christi, Tex.

PACIFIC PORTS

52 - Long Beach, Calif.

53 - Stockton, Calif.
San Francisco, Calif.
Oakland, Calif.

54 - Portland, Ore.
Astoria, Ore.
Vancouver, Wash.
Longview, Wash.
Kalama, Wash.

55 - Seattle, Wash.
Tacoma, Wash.

Figure 11. Specification of Demand Points for Grain Exported From the United States

(1) proximity to the center of the region's major grain production area, and (2) proximity to major rail lines so that rail rates may be more accurately specified. Grain storage facilities were assumed to be located at these points. Grain destination (consumption) points were selected with reference to major population centers within a particular region, and grain processing facilities were assumed to be located at these points. The towns and cities chosen to represent production and consumption points in each region are presented in Table II.

Once a regional demarcation is decided upon, the next step in model implementation is that of generating or collecting the various types of input data required. The transhipment model proposed in Chapter III requires four types of regional data. They are: (1) regional supplies of each grain by time period, (2) regional demands (consumption) of each grain by time period, (3) regional capacities in storage and processing, and (4) marketing costs and/or charges for performing various functions. The sources and methodology in generating these basic data are discussed below.

Regional Supplies

The term "supply" is not used in a functional sense in this study but simply refers to the quantity of a product that is available in the various regions. These quantities were preassigned to the respective regions in the model and were not allowed to vary. This usage is quite common in most discussions and applications of transhipment models.

TABLE II

REGIONAL BASING POINTS FOR GRAIN ORIGINS AND DESTINATIONS

Code	State	Grain Origin	Grain Destination
1	New England	Northampton	Boston
2	New York	Canadaigua	New York
3	Deleware, Md, Penn, and New Jersey	Altoona	Philadelphia
4	Ohio	Marysville	Mansfield
5	Indiana	Kokoma	Indianapolis
6	Illinois, North	Peoria	Chicago
7	Illinois, South	Mt. Vernon	East St. Louis
8	Michigan	Albion	Detroit
9	Wisconsin	Madison	Fondulac
10	Minnesota, North	Fergus Falls	Duluth
11	Minnesota, South	New Ulm	Minneapolis
12	Iowa, North	Algona	Mason City
13	Iowa, South	Chariton	Des Moines
14	Missouri	Brunswick	Jefferson City
15	North Dakota	Findley	Minot
16	South Dakota	Huron	Sioux Falls
17	Nebraska	Central City	Lincoln
18	Kansas, North	Russell	Topeka
19	Kansas, South	Pratt	Wichita
20	Virginia and West Va.	Farmville	Richmond
21	North Carolina	Dunn	Rocky Mount
22	South Carolina	Sumter	Laurens
23	Georgia	Fitzgerald	Atlanta
24	Florida	Cottondale	Tampa
25	Kentucky	Eddyville	Louisville
26	Tennessee	Waverly	Jackson
27	Alabama	Clanton	Birmingham
28	Mississippi	Greenwood	Jackson
29	Arkansas	Wynne	Little Rock
30	Louisiana	Pineville	Baton Rouge
31	Oklahoma	Waynoka	Oklahoma City
32	New Mex., Texas, West	Littlefield	Amarillo
33	Texas, South	Beeville	Houston
34	Texas, East	Cisco	Ft. Worth
35	Montana, East	Wolfe Point	Miles City
36	Montana, West	Conrad	Great Falls
37	Wyoming	Wheatland	Casper
38	Colorado	Limon	Denver
39	Arizona	Tucson	Phoenix
40	Utah, Idaho	Pocatello	Ogden
41	Washington, Oregon	Othello	Portland
42	Nevada, California	Modesto	Fresno

The usual components of supply in a spatial equilibrium model are production and beginning inventories. Since this study is concerned with the marketing system for grain and the optimum use of the facilities involved in this system, only that proportion of the total supply that moved through commercial marketing channels and competed for the limited capacities was considered. Thus, the relevant components of supply were off-farm sales of the 1966 crop[1] and off-farm (commercial) stocks[2] of previous crops on hand as of July 1, 1966.

Since a time-staged model was employed in the quarterly analysis, allocation of off-farm sales among the various quarters of the marketing year was necessary. The usual harvesting dates in all producing areas were determined, and it was assumed that grain sold off-farm moves into the commercial marketing channel during the quarter in which harvest usually takes place.[3] Given this assumption, all wheat entered the system in the July-September quarter. In most principal producing areas larger quantities of feed grain and soybeans were harvested during the fall quarter than during the summer quarter. Thus, off-farm sales of feed grain and soybeans were allocated between the two quarters based on usual harvest dates.

Three types of wheat were considered as separate and distinct grains. The types considered were (1) hard wheat, (2) soft wheat, and (3) durum wheat. The hard wheat classification included hard red winter and hard red spring classes of wheat. These wheats are used primarily in making yeast breads and rolls. The soft wheat classification included soft red winter and white classes of wheat. These wheats are used primarily in making quick breads, cakes and crackers. Durum wheat is quite different from the above classes of wheat and is used to make macaroni and spaghetti. Durum is milled in a small number of highly specialized milling units and does not compete with the other types of wheat for flour milling capacity. Thus, it was desirable to consider durum as a separate type of wheat.

Wheat is grown throughout the United States; however, the producing regions for the various classes of wheat are fairly distinct. Hard red winter wheat is grown principally in the Southern Great Plains, and hard red spring and durum wheats are grown in the Northern Great Plains. Soft red winter wheat is grown in most all Eastern, Southern, and Mid-western states while most white wheat production is found in the Northwest.

Determining regional supplies of the three types of wheat specified above presented a problem because data on off-farm sales and stocks were not available by class of wheat. To overcome this problem, the percentage of total wheat acreage in each state occupied by each class was determined and total off-farm sales and stocks for each state or region were allocated accordingly.[4] The estimated regional supplies of each type of wheat are presented in Table III.

Feed grains are those grains grown primarily for livestock feeding. Feed grain as used in this study includes corn, oats, barley, and grain sorghum. These grains were assumed to be perfect substitutes and were treated as a single grain in the model. The estimated off-farm sales in the July-September quarter were aggregated with July 1 stocks to determine the available supply in each region during this quarter and are presented in Table III.

The estimates of off-farm sales of feed grain during the October-December quarter are presented in Table IV by region. These quantities

TABLE III

ESTIMATED REGIONAL SUPPLIES OF GRAIN AVAILABLE IN JULY-SEPTEMBER QUARTER BY TYPE OF GRAIN, 1966

Region	Hard Wheat	Soft Wheat	Durum Wheat	Feed Grain	Soybeans
			10,000 Bu.		
1	0	0	0	197	0
2	367	2,140	0	1,309	0
3	565	1,943	0	2,152	0
4	42	4,325	0	5,170	517
5	157	3,804	0	4,183	2,901
6	1,697	642	0	7,596	5,077
7	2,473	1,302	0	5,289	3,647
8	28	3,080	0	2,281	70
9	1,253	474	0	5,240	10
10	2,422	260	1,727	5,273	617
11	1,770	0	1,600	7,784	1,083
12	325	0	0	6,590	786
13	423	0	0	12,921	1,000
14	2,629	2,198	0	3,807	4,497
15	13,188	0	6,349	12,624	460
16	6,095	0	416	10,458	456
17	11,724	0	0	20,234	108
18	13,937	0	0	5,129	156
19	13,936	0	0	3,605	156
20	55	486	0	398	0
21	0	438	0	880	160
22	0	174	0	322	102
23	0	185	0	1,231	0
24	0	61	0	141	0
25	0	533	0	2,957	197
26	0	420	0	400	733
27	0	158	0	393	110
28	0	744	0	199	347
29	131	987	0	335	1,402
30	85	195	0	631	440
31	10,863	0	0	3,041	138
32	6,307	0	0	27,224	137
33	571	0	0	6,858	0
34	3,446	0	0	12,253	5
35	4,249	369	297	1,821	0
36	5,718	110	231	3,509	0
37	459	13	0	239	0
38	4,560	0	0	1,623	0
39	24	85	0	1,439	0
40	2,487	2,119	0	2,115	0
41	3,208	12,517	0	4,446	0
42	70	1,085	30	9,028	0

TABLE IV

ESTIMATED OFF-FARM SALES OF FEED GRAIN AND SOYBEANS BY REGION, OCTOBER-DECEMBER QUARTER, 1966

Region	Feed Grain	Soybeans	Region	Feed Grain	Soybeans
	10,000 Bu.			10,000 Bu.	
1	16	0	22	649	1,864
2	309	5	23	2,302	666
3	2,517	537	24	552	213
4	12,267	5,808	25	0	763
5	22,190	4,840	26	1,382	2,088
6	39,175	3,916	27	743	674
7	12,598	5,983	28	409	4,244
8	3,618	1,049	29	405	8,189
9	2,307	319	30	213	2,045
10	4,745	1,399	31	0	142
11	3,646	5,598	32	7,676	197
12	11,370	5,873	33	1,870	3
13	25,308	8,810	34	2,804	18
14	6,826	4,350	35	67	0
15	426	73	36	102	0
16	1,233	239	37	33	0
17	27,665	2,259	38	1,459	0
18	7,090	1,197	39	1,048	0
19	4,347	798	40	79	0
20	727	630	41	113	0
21	3,055	2,031	42	2,448	0

were introduced into the time-staged model during the second quarter as supplies, and the total regional quantity of each grain available in the fall quarters was these sales plus any regional inventories internal to the model that were not needed to satisfy the regional feed grain demands during the summer quarter.

Soybean production in the United States has expanded rapidly in recent years, and current production is almost a billion bushels. This expanded production has made soybeans a major competitor for storage space in many of the major grain producing states. For this reason, soybeans were included in this study of the grain marketing system.

The same procedure that was used above to estimate the quantities of feed grain available by quarter was employed with respect to soybeans. The total supply available in each region during the summer quarter and off-farm sales during the fall quarter are presented in Tables III and IV, respectively.

Regional Demands

The term "demand" is used throughout this study to refer to the quantity of a particular product that a region must obtain through the marketing system to satisfy its requirements during the period under consideration. This terminology is common in discussions related to transportation models even though the term is used in theory to refer to a schedule depicting a price-quantity relationship.

Regional Wheat Demands

Domestic disappearance of wheat in the United States involves the following uses: (1) processed for food, (2) seed, (3) industrial, and

(4) livestock feed. During the 1960's exports of wheat and flour have been greater than domestic disappearance.

Regional data were not available for 1966-67 for quantities used in livestock feeding in excess of those quantities fed on farms where produced and were omitted from consideration. Thus, domestic disappearance was underestimated by approximately 60 million bushels. The exclusion was compensated for in estimating regional uses of feed grain for livestock feeding. Thus the net effect on the results was a slight increase in ending wheat inventories and a corresponding decrease in feed grain inventories. The other four domestic uses as well as wheat and flour exports were given consideration in the model, and regional requirements are discussed below.

Flour Demands

The processing of wheat into food was by far the most important domestic use. During the year July 1966-June 1967 about 74 percent of total domestic disappearance was consumed as food, and almost all of this wheat was milled into flour by the flour milling industry. Flour millers' demand for wheat is a derived demand associated with the demand for the various types of flour in each region. Hence, the demand for wheat for food except for durum was accounted for in the model through the regional demands of hard-wheat and soft-wheat flours. Very little information was available on the distribution of durum flour beyond the mill so the durum sector of the wheat-flour economy was not extended beyond assembly of wheat at mill points.

Domestic consumption of hard-wheat and soft-wheat flours for the period July 1966-June 1967 was estimated to be equivalent to about

337 and 150 million bushels of wheat, respectively. Exports of these flours were equivalent to about 51 and 3 million bushels, respectively. An estimated 22.5 million bushels of durum wheat were milled by domestic mills during the same period. In terms of domestic food usage, hard wheat, soft wheat and durum wheat accounted for about 66, 30 and 4 percent of the total, respectively.

Results of previous research by the Product and Process Evaluation Staff of Agricultural Research Service were used as a basis for estimating the amount of hard-wheat flour and soft-wheat flour consumed in each of the 42 domestic regions. A 1963 article by H. Wayne Bitting and Robert O. Rogers presented a breakdown of domestic disappearance of wheat flour by state and by type (hard, soft, and durum) for the year 1959-1960 based on these earlier research efforts.[5] These state consumption data were adjusted to 1966 per capita consumption estimate of 111 pounds[6] and adjusted to reflect population changes in each state between July 1, 1960 and July 1, 1966.[7] No adjustments were made for changes in the relative importance of each type of wheat between 1960 and 1966 so regional differences in taste and preferences related to wheat products were assumed to be the same in 1966 as they were in 1960. The state estimates for 1966-67 were aggregated to conform to the regional demarcation developed for this study, and the regional estimates are presented in Table V.

The only significant industrial use of wheat was 558,915 hundredweights of flour used in the production of distilled spirits in Kansas.[8] Since this is the only industrial use considered in this study, 50 percent of this amount was included with the domestic flour requirements of each Kansas region (Table V).

TABLE V

ESTIMATED REGIONAL FLOUR REQUIREMENTS[a] (WHEAT EQUIVALENTS) BY TYPE OF FLOUR, JULY 1966-JUNE 1967

Region	Hard-Wheat Flour	Soft-Wheat Flour	Region	Hard-Wheat Flour	Soft-Wheat Flour
	10,000 Bu.			10,000 Bu.	
1	1,696	560	29	363	224
2	2,789	920	30	657	384
3	3,777	1,448	31	453	264
4	1,869	696	32	397	204
5	893	340	33	753	432
6	1,528	564	34	989	568
7	439	160	35	41	16
8	1,555	576	36	83	36
9	768	296	37	53	24
10	147	56	38	220	136
11	500	192	39	258	108
12	195	80	40	291	128
13	319	128	41	847	364
14	814	312	42	3,038	1,284
15	120	48	43	27	0
16	126	52	44	34	18
17	271	104	45	0	23
18	267[b]	80	46	0	0
19	267[b]	80	47	181	79
20	1,200	708	48	0	0
21	936	568	49	39	13
22	495	296	50	1,367	87
23	811	480	51	3,196	0
24	1,044	584	52	12	0
25	618	376	53	22	0
26	715	428	54	123	82
27	648	392	55	87	38
28	451	288			

[a]Export requirements exclude flour exports designated for relief since this information was not available by custom district.

[b]Kansas requirements include 558,915 cwts. of flour used in the manufacture of distilled spirits.

Data on flour exports from the United States during the 1966-67 marketing year were obtained from the Department of Commerce. The data excluded flour exports designated for relief because relief shipments were not available by custom district. The data were aggregated to conform to the export regions specified above and are also presented in Table V. Although most port regions handled some flour, about 86 percent of these export shipments moved through Gulf ports (regions 50 and 51).

Durum Wheat Processing

Durum wheat is used in the manufacture of semolina flour which in turn is used in the production of alimentary paste products. Semolina is manufactured by a small number of specialized milling units. Very little information was available on the distribution of semolina beyond the mills, so domestic food usage of durum wheat was introduced into the model as whole grain demands in milling regions. Per capita consumption of durum flour during 1966 was estimated to be 4.98 pounds.[9] Given this estimate and the population as of July 1, 1966, the estimated volume of durum wheat milled during the 1966-67 marketing year was 22.53 million bushels. This total was allocated among the regions having durum mills on the basis of the proportion of total milling capacity located in each region. The regional allocation of this total is presented in Table VI.

Wheat Exports

Wheat exports from the United States have been increasing rapidly in recent years and reached a record high of 786 million bushels during

TABLE VI

DURUM WHEAT PROCESSING: MILLING CAPACITY AND ESTIMATED VOLUME MILLED BY REGION, JULY 1966-JUNE 1967

Milling Region	Daily Capacity[a]	Estimated Mill Requirements[b]	
		Annual	Quarterly[c]
	Cwt.	10,000 Bu.	
2	4,600	239	60
9	9,700	505	127
11	18,000	936	234
15	4,000	209	53
41	7,000	364	91
Total	43,300	2,253	565

[a]Daily capacity as reported in The Northwestern Miller (Minneapolis, September, 1967), p. 72.

[b]The estimated annual disappearance of 22.5 million was allocated among regions on the basis of durum milling capacity.

[c]Twenty-five percent of annual requirements.

the 1965-66 marketing year. The volume decreased to about 666 million bushels during 1966-67 (the year under consideration in this study); however, this level was about 10 million bushels higher than the average for the 1960's. Generally speaking, the 1966-67 year was a fairly representative year for wheat exports during the 1960's.

The volume of each type of wheat exported was determined from published data on inspections for export by type of grain and port. The data were based on weekly reports of inspections for export by licensed grain inspectors during 1966-67 and did not include rail and truck movements to Canada or Mexico. The data are presented in Table VII by type of wheat and port region.

Seed Requirements

Approximately 6 percent of the 1966 crop, or 78.35 million bushels, was used for seeding the 1967 crop. Over 44 million bushels of these needs were satisfied by quantities used for seeding on farms where produced, and about 34 million bushels were procured from off-farm sources. The latter amount was the relevant amount from the standpoint of this study since the quantity remaining on farm did not enter the marketing system and compete for storage facilities. The regional demands were computed by first determining the total quantity used for seed by type of wheat and deducting the proportion used on farms where produced. The estimated regional quantities procured from off-farm sources are presented by type of wheat and quarter in Table VIII. The allocation by quarter was based on the usual planting dates in the various regions.[10] Hard red spring and durum wheats were usually planted during April and May, and the other classes were planted during late

TABLE VII

INSPECTIONS OF WHEAT FOR EXPORT FROM UNITED STATES BY PORT AND QUARTER, JULY 1966-JUNE 1967

Port	Hard Wheat				Soft Wheat				Durum Wheat			
	July-Sept.	Oct.-Dec.	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Jan.-Mar.	Apr.-June
					10,000 Bu.							
43	494	600	0	260	0	0	0	0	728	1,457	0	564
44	18	21	0	0	9	43	0	45	0	0	0	0
45	0	0	0	0	130	577	0	601	0	0	0	0
46	575	178	62	0	56	2	180	126	83	0	0	0
47	1,602	827	1,067	132	200	560	200	163	0	0	231	58
48	536	234	278	277	190	93	137	327	0	160	501	155
49	50	0	56	45	15	0	0	0	0	0	0	0
50	3,015	2,540	1,666	964	1,361	661	633	1,385	210	94	328	97
51	6,625	6,806	4,287	3,097	0	0	0	0	0	0	61	9
52	34	0	0	0	8	0	0	0	0	0	0	0
53	14	3	0	0	12	0	0	0	0	0	0	0
54	1,285	1,363	1,324	1,838	1,856	2,820	2,346	2,283	24	10	6	12
55	371	276	102	540	580	591	556	627	0	0	0	0

Source: U. S. Department of Agriculture, Grain Market News, Consumer and Marketing Service, Grain Division, Vols. 14 and 15 (Hyattsville, 1966 and 1967), selected issues.

TABLE VIII

ESTIMATED REGIONAL DEMANDS FOR WHEAT FOR SEED BY QUARTER, 1967 CROP

Region	Hard Wheat		Soft Wheat		Durum
	July-Sept.	April-June	July-Sept.	Oct.-Dec.	April-June
			10,000 Bu.		
1	0	0	0	0	0
2	0	0	30	0	0
3	0	0	74	0	0
4	0	0	148	0	0
5	0	0	90	0	0
6	26	0	14	0	0
7	52	0	28	0	0
8	0	0	136	0	0
9	4	0	0	0	0
10	0	73	0	0	11
11	0	36	0	0	0
12	5	0	0	0	0
13	1	0	0	0	0
14	89	0	73	0	0
15	0	147	0	0	325
16	27	65	0	0	20
17	159	0	0	0	0
18	166	0	0	0	0
19	166	0	0	0	0
20	0	0	0	19	0
21	0	0	0	26	0
22	0	0	0	11	0
23	0	0	0	10	0
24	0	0	0	5	0
25	0	0	0	22	0
26	0	0	0	24	0
27	0	0	0	12	0
28	0	0	0	80	0
29	10	0	76	0	0
30	0	0	15	0	0
31	189	0	0	0	0
32	136	0	0	0	0
33	0	0	0	0	0
34	84	0	0	0	0
35	42	20	0	0	12
36	56	34	0	0	8
37	16	0	0	0	0
38	15	0	0	0	0
39	3	0	8	0	0
40	58	13	61	0	0
41	51	0	233	0	0
42	0	0	37	0	0

summer or early fall.

Regional Feed Grain Demands

Utilization of feed grain produced in the United States includes four major categories. They are (1) livestock feed, (2) seed, (3) industrial, and (4) exports. The distribution of the 1966 crop by type of use for the four major feed grains is presented in Table IX. As would be expected, the major use of these grains was for livestock feed. The industrial use involves a wide variety of products and the outlets represent very important markets for these grains. The major industrial uses of corn were wet processed products, cornmeal, hominy and grits, with lesser quantities being used in the manufacturing of breakfast cereals, alcohol and distilled spirits. Industrial use of grain sorghum was very limited with only 11 million bushels being used for alcohol, distilled spirits and wet processing. Oats were used only in breakfast foods. The major use of barley was for malting, although a small quantity of barley was used in food products and in the production of industrial alcohol and alcoholic beverages.

As was the case for wheat, large quantities of feed grain are exported from the United States. The volume of feed grain exported from the United States depends upon many variables and fluctuates a great deal from year to year. Feed grain exports during 1966-67 were considerably below the very high level of 1965-66 but were about average for the 1960's.

In the following sections, regional allocations of these aggregate volumes will be presented, and the methods used to derive regional estimates for the various uses will be discussed. Regional estimates

TABLE IX

ANNUAL DISTRIBUTION OF FEED GRAINS BY GRAIN, UNITED STATES, 1966 CROP

Use	Type of Grain			
	Corn	Sorghum	Barley	Oats
	Mil. Bu.			
Livestock feed	3,285.0	600.0	213.0	732.0
Seed	14.0	2.0	16.0	53.0
Industrial				
Wet processed products	205.0	8.3	0.0	0.0
Cornmeal, hominy and grits	112.0	0.0	0.0	0.0
Breakfast foods	20.0	0.0	6.0	49.0
Alcohol, beer and distilled spirits	33.0	2.7	0.3	0.0
Barley malt	0.0	0.0	102.7	0.0
Exports (grain)	466.0	248.0	43.0	17.0

Sources: U. S. Department of Agriculture, *Feed Situation*, Economic Research Service Pub. FdS-222 (Washington, February, 1968), pp. 8-9, and U. S. Treasury Department, *Alcohol and Tobacco Summary Statistics, Fiscal Year 1967*, Internal Revenue Service Pub. 67 (1967) (Washington, 1967), pp. 7 and 41.

for each use were necessary so the total feed grain requirement in each region could be derived by aggregating the individual uses.

Livestock Feed

The livestock industry is by far the largest user of feed grain, and the mixed feed industry is one of the largest industries devoted exclusively to supplying goods and services to agriculture. According to the 1963 Census of Manufacturers, about 2,600 plants were involved in the manufacture of livestock feed. The industry is highly decentralized, and most of the feed processing is done near the point of consumption. For these reasons, the feed processing activities were assumed to take place at points of consumption, and regional grain requirements for feeding were expressed as whole grain demands.

Several data sources were drawn together to construct estimates of the regional uses of feed grain for livestock feed. The total quantity of each feed grain used for livestock feed was determined (Table IX). These totals were combined and allocated among states in proportion to the total number of grain-consuming animal units fed in each state during the 1966 feeding year.[11] The state estimates of feed grain fed were then reduced by the amount of wheat and feed grain fed on farms where produced and aggregated on the basis of the 42 regions defined for the study.[12] The resulting quantities were used as estimates of the net yearly demand for feed grain from commercial sources to fulfill feeding requirements. The regional estimates were then allocated among the four quarters on the basis of actual 1964 domestic disappearances by quarters, and 22, 27, 29, and 22 percent of the estimated requirements were allocated to the summer, fall, winter and spring quarters, respectively.[13]

The quarterly estimates are presented by region in Table X.

Seed

The total domestic disappearance of feed grain for seeding purposes (Table IX) was allocated among states on the basis of planted acreage[14] for the 1967 crop, and allocated among the quarters on the basis of the usual planting dates.[15] The estimated quantities of seed demanded from commercial sources are presented in Table XI. In a few regions, the volume of wheat and feed grain fed on farms where produced exceeded the estimated requirements for livestock feed, and the excesses were deducted from seed requirements. In Minnesota and North Dakota (regions 10, 11, and 15) these excesses were sufficient to satisfy seed requirements, and the net demands for seed were zero. Soybean seed requirements are also presented in Table XI. These estimates will be discussed later.

Industry

Industrial use of feed grain involves a variety of uses and products. The industrial uses that were considered in this study were dry corn milling, wet processing, cereal manufacturing, malting, and brewing and distilling. These outlets are by no means as important as livestock feed and exports in terms of volume used, but they do represent important off-farm outlets for feed grain.

Regional data related to the industrial uses were almost nonexistent in all cases except that portion used in the manufacture of beer, alcohol and distilled spirits. Statistics on these uses were available from the Internal Revenue Service. Consequently, it was

TABLE X

ESTIMATED REGIONAL DEMANDS FOR FEED GRAIN FOR LIVESTOCK FEEDING BY QUARTER, JULY 1966-JUNE 1967

Region	July-September	October-December	January-March	April-June
		10,000 Bu.		
1	1,882	2,335	2,480	1,882
2	1,441	1,769	1,900	1,441
3	3,711	4,555	4,892	3,711
4	412	506	544	412
5	790	969	1,041	790
6	379	465	500	379
7	390	478	514	390
8	161	198	212	161
9	231	284	304	231
10	0	0	0	0
11	0	0	0	0
12	543	667	716	543
13	1,211	1,486	1,596	1,211
14	2,313	2,839	3,049	2,313
15	0	0	0	0
16	66	82	87	66
17	1,488	1,826	1,961	1,488
18	362	444	477	362
19	141	173	186	141
20	1,264	1,551	1,666	1,264
21	2,750	3,376	3,625	2,750
22	588	721	775	588
23	3,884	4,766	5,119	3,884
24	805	988	1,062	805
25	669	822	882	669
26	1,152	1,414	1,519	1,152
27	2,680	3,290	3,533	2,680
28	1,829	2,245	2,411	1,829
29	3,099	3,804	4,085	3,099
30	547	705	757	574
31	678	832	893	678
32	528	648	696	528
33	900	1,105	1,187	900
34	1,602	1,966	2,112	1,602
35	0	0	0	0
36	8	10	11	8
37	27	33	36	27
38	715	878	943	715
39	292	358	385	292
40	456	560	601	456
41	1,115	1,368	1,470	1,115
42	4,170	5,118	5,497	4,170

TABLE XI

ESTIMATED REGIONAL DEMANDS FOR FEED GRAIN AND SOYBEANS FOR SEED BY QUARTER, JULY 1966-JUNE 1967

Region	Feed Grain			Soybeans
	July-September	January-March	April-June	April-June
	10,000 Bushels			
1	0	0	24	0
2	2	0	142	1
3	55	0	185	20
4	3	0	229	109
5	3	0	206	133
6	1	116	70	118
7	2	180	110	144
8	4	0	180	39
9	0	0	546	15
10	0	0	0	33
11	0	0	0	133
12	0	0	258	140
13	0	448	123	211
14	0	101	61	217
15	0	0	0	18
16	0	649	127	21
17	8	177	94	58
18	22	43	66	26
19	15	26	39	17
20	57	0	14	17
21	70	0	28	64
22	55	0	10	44
23	53	0	28	27
24	7	0	7	8
25	24	0	20	41
26	42	0	17	96
27	34	0	19	42
28	32	0	16	178
29	33	0	6	244
30	17	0	4	126
31	142	0	10	92
32	247	0	17	19
33	81	0	6	0
34	121	0	10	1
35	0	0	127	0
36	0	0	257	0
37	0	0	52	0
38	56	38	15	0
39	0	27	1	0
40	0	148	2	0
41	0	217	2	0
42	0	354	7	0

necessary to devise estimating procedures for other uses. The purpose of such procedures was to allocate the aggregate data presented in Table IX.

Dry corn milling was the most widely distributed of all industrial users of feed grain with 152 mills located in 26 of the 42 regions under consideration. As a user of corn, the industry ranks third behind animal feed manufacturers and wet corn millers, and the annual grind is in excess of 100 million bushels. The major products are cornmeal, hominy and grits. In addition to being widely distributed, firm size is quite variable with daily capacity ranging from 10 hundredweights of corn meal up to 4,800 hundredweights. Dry corn mills were more prevalent in South Atlantic and East South Central regions with over two-thirds of the mills located in these regions in 1965.

Estimates of the volume of corn milled in each region were not available. However, the location and capacity of corn mills operating in the United States were determined from a corn milling industry directory published by The Northwestern Miller.[16] In several instances companies preferred to keep their capacity confidential, and these plants were assumed to have a capacity equivalent to the average capacity of other plants in the appropriate census region. Once estimated total milling capacity was determined for each of the 26 regions having mills (Table LVIII, Appendix), the 112 million bushels milled in the United States during 1966-67 (Table IX) were allocated among these regions in proportion to estimated capacity. The estimates of regional use by the corn milling industry are presented in Table XII.

The wet corn milling (corn refining) industry was the most important industrial user of corn and grain sorghum. The annual grind is

TABLE XII

ESTIMATED REGIONAL DEMANDS FOR FEED GRAIN FOR INDUSTRIAL USES BY USE, JULY 1966-JUNE 1967

Region	Corn Milling Dry	Corn Milling Wet	Cereal Manuf.	Barley Malt	Alcohol & Beer	Total
			10,000 Bushels			
1	0	271	186	0	0	457
2	14	4	1,096	584	0	1,698
3	430	90	297	47	658	1,522
4	100	200	49	47	0	396
5	564	2,405	363	0	490	3,823
6	379	5,844	683	2,035	270	9,211
7	321	5,116	0	0	270	5,707
8	0	0	2,205	351	0	2,556
9	126	0	0	4,327	0	4,453
10	0	0	0	0	0	0
11	0	0	217	1,848	0	2,065
12	0	0	0	0	24	24
13	497	4,536	998	0	24	6,055
14	915	1,439	9	163	4	2,530
15	0	17	0	0	0	17
16	0	0	0	0	0	0
17	291	0	364	0	0	655
18	0	0	9	0	128	137
19	85	0	9	0	128	222
20	845	0	0	0	9	854
21	873	0	9	0	0	882
22	209	0	0	0	0	209
23	427	17	9	0	7	460
24	159	17	0	0	0	176
25	1,072	0	0	0	1,403	2,475
26	2,193	0	665	0	64	2,922
27	346	0	0	0	0	346
28	91	0	0	0	0	91
29	0	0	0	0	0	0
30	0	0	0	0	5	5
31	414	0	31	0	0	445
32	13	0	0	0	0	13
33	366	603	0	0	0	969
34	374	32	9	0	11	426
35	0	0	18	0	0	18
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	51	0	0	0	51
39	0	0	0	0	0	0
40	0	247	0	0	0	247
41	46	23	9	351	0	429
42	48	394	466	514	6	1,428

currently in excess of 200 million bushels. The products of the wet process include starch, sirup, oil, sugar, etc.; the main product being starch. The industry is composed of a relatively small number of establishments when compared with other grain processing industries.

Disaggregated regional data were not available on the volume of grain used by wet processors, and plant capacities were not available for estimation purposes. Data on number and size of plants (defined by employment ranges) located in each region were ascertained.[17] Regional employment estimates were derived from these data (Table LIX, Appendix) based on the assumption that a plant within a particular employment range would have an employment equivalent to the midpoint of its range. The 1966-67 industry use of 213 million bushels of corn and sorghum was allocated among the regions in proportion to estimated employment. The quantities allocated to each region are presented in Table XII.

The barley malting industry annually uses around 100 million bushels of barley, and this represents about 40 percent of an average United States barley crop. The industry is confined to a relatively few firms owning only 42 malting plants (Table LX, Appendix). In 1963, 33 of these plants were located in the North Central region, 6 in the Middle Atlantic, and 3 in the Pacific states.[18] The procedure used to estimate region use of grain by the wet processing industry was employed to estimate regional use of barley by the malting industry, and the estimates are presented in Table XII.

The cereal processing industry is highly market orientated with plants located near major population centers. During 1966-67, the industry used about 75 million bushels of feed grain (Table IX), but data on regional use were not available. Again, this quantity was allocated among regions in proportion to regional employment estimates derived from industry data (Table LXI, Appendix), and the estimates of regional use are presented in Table XII.[19]

Data on actual use of feed grain in producing beer, alcohol and distilled spirits were obtained from Internal Revenue Service statistics.[20] These data were available by states, and regional allocation of aggregate data was not necessary. Regional uses are presented in Table XII.

Exports

Exports of feed grain were assumed to be the same as inspections for export. Data by type of grain and port were collected from monthly inspection reports published by the U.S. Department of Agriculture. Data for individual grains and ports were aggregated by export region to determine estimates of the demand for feed grain at each of the 13 export points during 1966-67. The regional estimates are presented by quarter in Table XIII.

Regional Soybean Demands

The major uses of soybeans produced in the United States are processing, seed, and exports. The actual volumes of soybeans processed (crushed) by quarter during 1966-67 were obtained from Fats and Oils Situation.[21] The aggregate volume crushed during each quarter was then allocated among the various regions in proportion to soybean crushing capacity. The crushing capacity was confidential information since some regions had only two plants. Consequently, estimates of the volume crushed in various regions could not be published here, even

TABLE XIII

INSPECTIONS OF FEED GRAIN AND SOYBEANS FOR EXPORT FROM UNITED STATES BY PORT AND QUARTER, JULY 1966-JUNE 1967

Port	Feed Grain				Soybeans			
	July-Sept.	Oct.-Dec.	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Jan.-Mar.	Apr.-June
				10,000 Bushels				
43	2,533	2,293	0	1,742	516	126	0	231
44	2,630	2,066	0	960	487	882	0	516
45	323	1,090	0	733	286	1,558	0	620
46	0	55	302	39	0	0	0	0
47	164	1,125	1,135	225	6	249	299[a]	23
48	346	787	647	238	5	215	148	60
49	2	12	6	20	28	291	340	213
50	8,874	9,881	10,896	8,180	1,535	6,350	5,237	4,521
51	6,614	4,573	3,542	4,461	0	90	52	4
52	829	1,340	1,238	777	0	0	0	0
53	94	311	391	128	0	0	0	0
54	40	504	637	359	0	0	0	0
55	262	0	6	10	0	0	0	0

[a]A small quantity of soybeans that were exported through area 46 in January-March quarter were included in area 47.

Source: U. S. Department of Agriculture, Grain Market News, Consumer and Marketing Service, Grain Division, Vols. 14 and 15 (Hyattsville, 1966 and 1967), selected issues.

though the data were used as inputs in this study.

The total quantity of the 1966 soybean crop used for seed was determined for each region from published data.[22] These quantities were adjusted downward by the amount of beans used for seed on farms where produced to determine the volume procured from commercial sources. The regional requirements for seed are presented in Table XI.

The volume of soybeans exported by quarter during 1966-67 were determined from the monthly volumes of soybeans inspected for export in the port regions. The total inspections by region and quarter are presented in Table XIII.

The model proposed for this study allowed for a single estimate of the volume used in each region in the case of feed grain and soybeans. Hence, the estimated regional requirements for the various uses were aggregated together, and a single quantity of feed grain and of soybeans demanded in each region were used as input data for the analyses. Aggregating all feed grains together on a bushel basis is not very desirable but was necessary since grain storage capacity was incorporated into the model. The only alternative would have been to expand the model to include eight grains and this would have greatly exceeded the available data processing capacity.

Regional Capacities

The model formulated in Chapter III requires estimates of grain storage and flour milling capacity for each of the 42 regions under consideration. The ideal model would be one that included a separate specification of capacity for each plant within the industries involved. Such an approach was impractical, and capacities of all plants within a region were combined.

Grain Storage

The grain handling and storage industry occupies a position of importance in the grain marketing system. The importance of storage stems from the seasonal nature of grain production. While production is seasonal, grain processing and consumption takes place throughout the marketing year. The storage industry performs the function of matching supplies and demands over this period. Thus, a dynamic time element is added to the marketing system by the storage industry.

The handling and storage industry is composed of three types of facilities. These are country elevators, terminal elevators, and CCC binsites. Data on location and capacity of CCC binsites were not available and were omitted from consideration.

The country elevator is and traditionally has been the first stage in the grain marketing process. The primary function of a country elevator is to serve as a market outlet for off-farm sales of whole grain, and they are found in all grain-producing regions of the United States. Consequently, these firms are the primary assemblers of whole grain and, in turn, serve as a source of whole grain for processors and terminal elevators.

The terminal sector of the storage industry is composed of "sub-terminal" and "terminal" elevators, and both types may have inland or port locations. In general, subterminal elevators are located in grain production regions while terminals are located in the traditional grain marketing centers such as Minneapolis and Chicago. Location rather than size determines whether an elevator is classified as "terminal."

The primary functions of inland terminals are storage and merchandising of grain.

In recent years large country and subterminal elevators have been constructed near the grain producing areas. Many of these facilities provide most of the services such as cleaning, drying, blending and storing that were traditionally provided only at terminal facilities. As a result, the traditional terminal markets have become less important, and a breakdown of the storage industry into "country" and "terminal" would be quite arbitrary. Because of this and a desire to keep the size of the problem down as much as possible, the decision was made to combine all inland off-farm storage rather than incorporating two levels of storage in the model. The estimates of total inland, off-farm storage capacity in each of the 42 domestic regions are presented in Table XIV.

In addition to the country and terminal elevators making up the inland storage capacity, a large number of elevators are classified as port elevators. Although port elevators have storage space, the capacity is used primarily for the accumulation of grain prior to the loading of ocean going ships rather than for long-term storage. Accumulation of grain at port elevators is necessary because the large ocean going ships have capacities to carry about 80,000 long-tons of grain, and to load a ship of this capacity requires inventories at a port elevator of about 3 million bushels. Loading of ships directly from trucks or rail cars is impractical because a large ship would hold an equivalent of about 900 rail hopper cars of grain (11 eighty-car trains) and to schedule the arrival of such a volume exactly when ships are ready for loading would be practically impossible.

TABLE XIV

ESTIMATED REGIONAL GRAIN STORAGE CAPACITY, 1967

Region	Storage Capacity	Region	Storage Capacity
	10,000 Bu.		10,000 Bu.
1	427	29	10,545
2	5,492	30	2,628
3	4,408	31	23,600
4	13,371	32	57,226
5	16,805	33	9,722
6	38,287	34	21,066
7	11,204	35	3,082
8	5,882	36	2,823
9	6,209	37	644
10	9,096	38	8,333
11	28,716	39	1,600
12	20,479	40	5,950
13	38,231	41	17,015
14	20,178	42	9,732
15	17,327	43	5,203
16	15,388	44	5,822
17	57,153	45	1,909
18	50,415	46	1,382
19	37,322	47	1,746
20	928	48	711
21	2,730	49	64
22	1,465	50	2,487
23	1,900	51	4,544
24	293	52	327
25	2,334	53	1,085
26	3,852	54	2,855
27	1,121	55	1,271
28	2,568		

Source: U. S. Department of Agriculture, Economic Research Service, Marketing Economics Division, Fibers and Grains Branch (Washington).

The location and storage capacity of dockside-port facilities were determined from information provided by the Agricultural Stabilization and Conservation Service. The capacities were grouped according to the port regions specified in Figure 11 and are presented in Table XIV. These capacities include only those elevators having dockside-port facilities equipped to load ships.

Flour Milling

The flour milling industry is the most important of the grain processing industries in the United States. Today millers grind wheat into more than $2 billion worth of flour and meal each year. The flour milling industry's output reached an all time peak during 1947 when the quantity milled was in excess of 305 million hundredweight.[23] This output level was associated with the emergency feeding period following World War II, and exports were at a record high of 100.4 million hundredweight. This was followed by a period of mill closings as flour exports declined to approximately 17 million hundredweight by 1954.

Since 1947 there has been a general trend of declining numbers in the flour milling industry. During the six year period from 1961 to 1967, the number of active flour mills declined from 549 to 358, representing a decrease of 35 percent, Table XV. However, during this period, average plant capacity increased from 1,849 hundredweight per day to 2,649 hundredweight per day, an increase of 43 percent, and the total capacity decreased less than 7 percent. Thus the effects of mill closings on total capacity were almost offset by plant expansion and the construction of larger plants. In fact, total milling capacity actually increased after 1965 while the number of plants continued to

TABLE XV

ACTIVE FLOUR MILLS,[a] NUMBER AND CAPACITY BY REGION, U. S. REGIONS, SELECTED YEARS

Region[b]	1961			1965			1967		
	Active Mills	Daily Capacity	Average Daily Capacity	Active Mills	Daily Capacity	Average Daily Capacity	Active Mills	Daily Capacity	Average Daily Capacity
	Number	Hundredweight		Number	Hundredweight		Number	Hundredweight	
New England	2	800	400	----	----	----	----	----	----
Middle Atlantic	68	117,560	1,729	74	118,998	1,608	59	121,684	2,062
South Atlantic	136	64,835	477	102	53,036	521	83	50,266	606
North Central	181	543,163	3,001	127	516,870	4,070	113	522,290	4,622
South Central	100	140,471	1,405	73	119,446	1,636	58	112,633	1,942
Mountain	38	52,066	1,370	27	46,707	1,730	26	53,567	2,060
Pacific	24	96,480	4,020	19	81,230	4,275	19	87,820	4,622
United States	549	1,015,375	1,849	421[c]	936,287[c]	2,224	358[c]	948,260[c]	2,649

[a]These data do not include mills milling durum wheat flour.

[b]Regions are those standard regions used by the Bureau of the Census.

[c]Data exclude one mill each in Hawaii and Puerto Rico having daily capacities of 2,000 and 4,000 hundredweight, respectively.

Sources: National Commission on Food Marketing, Organization and Competition in the Milling and Baking Industries, Technical Study No. 5 (Washington, 1966), p. 13 and The Northwestern Miller (Minneapolis, September, 1967), p. 9.

decline. The large mills were generally found in the North Central and Pacific regions while a large number of small mills were located in the South Atlantic region. The average plant capacity for the Middle Atlantic region is misleading in that during 1967 Pennsylvania had 45 mills with an average daily capacity of 489 hundredweight while New York had 13 mills with an average daily capacity of 7,282 hundredweight. The capacity ranged from a low of 20 hundredweight in Pennsylvania to a high of 30,200 hundredweight per day for a mill owned by the Pillsbury Company in Buffalo.

The location and capacity of the 358 flour mills operating during 1967 were obtained from a directory of the flour milling industry.[24] Capacities of individual mills within each of the 42 domestic regions were aggregated, and the regional totals are presented in Table XVI. Capacity of inactive mills were included in the regional totals because these mills could have been activated in the event they were needed. Five of the 42 regions did not have flour mills (regions 1, 12, 29, 30 and 35) and were excluded from Table XVI.

Marketing Charges and Costs

The final data category and perhaps the most important from the standpoint of accurate results is marketing charges and/or costs of performing various functions involved in grain marketing. The model developed for this study requires as input four types of cost data. They are (a) transportation rates between the grain origins and grain destinations, (b) handling costs for receiving and shipping grain, (c) storage charges, and (d) costs of milling wheat into flour. The costs of performing such activities as cleaning and drying of grain

TABLE XVI

REGIONAL FLOUR MILLING CAPACITY, 1967

Region	Active Daily Capacity	Inactive Daily Capacity	Total Daily Capacity	Yearly Capacity[a] (Wheat Equiv.)
	Cwt.	Cwt.	Cwt.	10,000 Bu.
2	94,666	-	94,666	5,596
3	33,862	100	33,962	2,008
4	60,270	1,000	61,270	3,624
5	28,070	-	28,070	1,660
6	21,590	-	21,590	1,276
7	31,450	-	31,450	1,860
8	29,950	-	29,950	1,772
9	160	-	160	8
10	2,175	-	2,175	128
11	69,615	-	69,615	4,116
13	20,700	-	20,700	1,224
14	84,190	-	84,190	4,980
15	7,000	-	7,000	412
16	2,700	300	3,000	176
17	28,430	-	28,430	1,680
18	60,050	-	60,050	3,552
19	75,940	2,400	78,340	4,632
20	11,396	-	11,396	672
21	22,256	-	22,256	1,316
22	3,430	1,200	4,630	272
23	3,830	-	3,830	228
24	2,500	-	2,500	148
25	4,519	-	4,519	268
26	29,474	-	29,474	1,744
27	6,500	-	6,500	384
28	400	-	400	24
31	25,700	3,600	29,300	1,732
32	1,060	-	1,060	64
33	7,100	7,300	14,400	852
34	37,880	2,600	40,480	2,392
36	10,180	-	10,180	600
37	2,700	-	2,700	160
38	11,880	-	11,880	704
39	840	-	840	48
40	27,047	-	27,047	1,600
41	52,600	-	52,600	3,112
42	35,220	-	35,220	2,084

[a]Assumes a year of 254 operating days.

Source: The Northwestern Miller (Minneapolis, September, 1967), p. 9.

were excluded from the study since the need for these activities is dependent upon the condition of the grain sold off-farm, and a basic assumption of the transportation model is that each product is of uniform quality.

Transportation Rates

Multiproduct spatial problems require a very large number of transportation rates between the various regions. In grain transportation, more than one mode of transportation is usually available to the shipper, and in many cases combination rates must be considered involving barges and either trucks and/or rail. Thus, the collection of transportation rates for a study of this nature is a major undertaking. The transfer charges associated with each of the three modes of transportation are discussed below.

Truck Transportation Rates

Previous research concerning the movement of grain in the North Central region of the United States indicates that an equation of the form

$$Y = A_0 + A_1X + A_2X^2 + \ldots + A_nX^n$$

where

Y = transportation rate

X = miles

is useful in estimating truck rates.[25] Mileage is an important factor in rate making by trucking firms, and mathematical equations expressing the relationship between rates and mileage were employed to estimate truck transportation rates for this study. The Texas Transportation

Institute in cooperation with the Marketing Economics Division of ERS collected rate data from various sources for the purposes of developing a set of regression equations. Interviewers from the Institute personally contacted 43 country and terminal elevators and 14 flour mills in collecting data, and additional data were collected from several secondary sources including truck brokers and published tariffs. A set of regression equations were developed and provided to the author for incorporation into this study.[26]

Estimation of these equations employed a computer program permitting regression of all degrees of polynomials up to a specified degree. An F-test was computed to determine if the reduction in the residual sum of squares was significant at the .99 level with succeeding higher degree polynomials. Thus, the lowest degree equations which "adequately" explained the data were chosen.

Truck rates for this study were computed for each grain using the "best-fit" equation for 10 to 30 ton truck shipments. In general, the third degree polynomial equation provided the "best-fit" for rates on shipments of 10 to 30 tons. Since rates were computed for each individual grain and feed grains were combined in this study, the rates for the predominant feed grain grown within a region were applied to all feed grain shipments from that region.

The regression equations used to compute truck transportation charges are presented below by type of grain.

WHEAT

$$Y = 3.6987165 + 0.0871990X + 0.0000139X^2 - 0.000000067X^3$$

$$s = 2.178501$$

$$r^2 = 0.966191$$

$$n = 272 \qquad (13)$$

CORN

$$Y = 1.8593640 + 0.1250674X - 0.0001984X^2 + 0.000000216X^3$$

$$s = 2.314911$$

$$r^2 = 0.952412$$

$$n = 246 \qquad (14)$$

OATS

$$Y = 5.6934370 + 0.1679232X - 0.0004285X^2 + 0.000000469X^3$$

$$s = 4.898500$$

$$r^2 = 0.854819$$

$$n = 83 \qquad (15)$$

BARLEY

$$Y = 4.1490884 + 0.0883299X - 0.0000211X^2$$

$$s = 1.793721$$

$$r^2 = 0.973186$$

$$n = 173 \qquad (16)$$

SORGHUM

$$Y = 4.190913 + 0.111452X - 0.000162X^2 + 0.000000179X^3$$

$$s = 2.024156$$

$$r^2 = 0.978988$$

$$n = 62 \qquad (17)$$

SOYBEANS

$$Y = 2.48022 + 0.121817X - 0.000192X^2 + 0.000000216X^3$$

$$s = 2.034939$$

$$r^2 = 0.970067$$

$$n = 136 \qquad (18)$$

BULK FLOUR

$$Y = 6.6370335 + 0.151605X$$

$$s = 1.675839$$

$$r = 0.986926$$

$$n = 85 \qquad (19)$$

where

Y = transportation rate in cents per 100 pounds,

X = miles,

s = standard deviation in cents per hundredweight,

r = coefficient of determination, and

n = number of data points.

Trucking charges to a great extent are based on operating costs, and as a result usually are closely related to mileage as the above equations demonstrate. However, they can show significant variation if "backhauls" are involved. The influence of such factors is beyond the scope of this analysis and were not considered. Truck shipments were not allowed beyond distances of 700 miles for wheat and 600 miles for other grains and flour in this study because the regression equations presented above might not have been applicable for greater distances.

Rail Transportation Rates

Rail is, and traditionally has been, the most important carrier of grain and flour; however, trucks and barges have increased their share of the traffic in recent years. The rate structure for rail transportation of grain has developed over many years and is based on many factors in addition to distance. Consequently, attempts to develop mathematical equations relating rates and mileage have not provided reliable estimates of rail rates, and this approach was not used in this study.

Actual point-to-point rates for domestic and export shipments were compiled by the Marketing Economics Division of ERS in cooperation with the Commodity Operations Division of Agricultural Stabilization and Conservation Service. The rates were "the most favorable commonly utilized rates." Generally, they were the lowest point-to-point rates available; however, if a multi-car rate was authorized between particular regional points but was merely a "paper rate," the higher single car rate was selected as the appropriate one. "Rent-a-train" and "unit train" rates were not introduced into the study because the level of rent-a-train rates are dependent upon the volume hauled, and very high minimum tonnage restrictions are associated with the unit-train rates. Both factors would create problems in model formulation if these rates were incorporated in the model.

Barge Transportation Rates

Barge rates used in this study were provided by Arrow Transportation Company and were the published rates in effect during 1967.[27] In general, published barge rates are probably higher than actual charges for contract shipments, but information was not available on the level of these charges or the extent to which they were used. Since grain is exempt from regulations when moved in accordance with Section 303(b) of the Interstate Commerce Act, barge lines have freedom to negotiate charges with shippers; however, due to a lack of information, published tariffs were used.

In most cases water transportation was not available for the complete movement between particular origins and destinations. Therefore, point-to-point barge-truck and barge-rail combination rates were computed where appropriate for interregional movements.

Incorporation of Rates Into the Model

Once point-to-point or combination rates were compiled, loading and receiving costs (Table XVII) were then combined with the rates for each mode of transportation. The resulting cost coefficients represented the total cost associated with interregional movements of grain and flour. The total cost associated with shipments by each mode of transportation were compared for each possible movement and the coefficient for the "least-cost" mode was used as input for the mod model. It was assumed that when alternative modes of transportation were available the "least-cost" mode would be utilized and that mode would have sufficient facilities (trucks, rail cars, and barges) available to haul the desirable volume.

Handling Costs

The cost associated with receiving and shipping grain varies depending upon mode of transportation used. Thus, the assignment of a particular charge for these services would not be very realistic. Regional estimates of handling costs at commercial elevators were developed by ERS by mode of transportation and type of storage facility for 1967-68.[28] Since no distinction was made in the model between country and terminal storage facilities and costs were reported by type of facility, a weighted average cost was calculated for all facilities in a region by weighting the estimate for each type of facility according to the proportion of total capacity represented by each type of ıacility in the region. The costs are presented by mode and function

TABLE XVII

ESTIMATED COSTS OF HANDLING GRAIN IN COMMERCIAL ELEVATORS BY GEOGRAPHIC AREA, TYPE OF FACILITY AND MODE OF TRANSPORTATION, 1967-68

Area and Facility	Received by --			Shipped by --		
	Truck	Rail	Water	Truck	Rail	Water
			Cents Per Bushel			
North Plains[a]						
Inland elevators	1.95	4.81	--	3.50	2.71	1.00
Port elevators	--	--	--	--	--	--
Mid-Plains[b]						
Inland elevators	2.28	2.87	--	2.36	3.56	--
Port elevators	--	--	--	--	--	1.00
South Plains[c]						
Inland elevators	3.07	10.50	--	3.38	4.19	--
Port elevators	1.60	1.20	1.20	2.30	3.10	0.80
West[d]						
Inland elevators	2.64	7.55	--	3.45	3.15	--
Port elevators	2.00	2.30	1.20	2.00	4.20	1.50
Great Lakes[e]						
Inland elevators	2.47	6.75	--	2.49	3.08	--
Port elevators	1.30	3.00	1.10	4.30	2.60	1.40
South and East[f]						
Inland elevators	1.95	3.86	2.00	3.20	2.18	--
Port elevators	1.30	1.80	4.00	3.90	2.40	1.00

[a]N. Dak., S. Dak., and Minn. (excluding port facilities).

[b]Nebr., Kans., Colo., Wyo., Iowa, and Mo.

[c]Okla., N. Mex., and Texas plus all gulf port facilities.

[d]Wash., Ore., Idaho, Mont., Calif., Ariz., Nev., and Utah.

[e]Wis., Ill., Ind., Ohio, Mich., and Minn. port facilities.

[f]Ark., Miss., S. C., Tenn., Ky., N. Y., Va., Pa., N. J., Md., Del., La., Ala., Ga., N. C., W. Va., and New England (excluding port facilities).

in Table XVII. These costs were then combined with transportation rates by the various modes of transportation to arrive at total interregional transfer charges.

Storage Charges

The charges for grain storage presented the most difficult problem of any of the marketing charges required in the model. Average per bushel cost for a firm is highly dependent upon capacity utilization with average cost decreasing as the percent of capacity utilized increases. The employment of such functional relationships was not desirable since firms were not considered individually in the model, and the cost-volume relationships at the firm level would lose their meaning when the capacities of all firms were combined within a region. Furthermore, specifying an average cost per bushel per quarter is not realistic, since the volume stored in any region in a particular quarter is determined within the model and varies from one quarter to the next.

Incorrect specification of storage cost could introduce serious distortions into an optimal solution. Given this fact and the difficulties involved in specifying regional storage costs, the decision was made to use the standard storage charges of the Commodity Credit Corporation's Uniform Grain Storage Agreement.[29] There are good indications that the charges made by elevator operators for storing commercial stocks of grain are closely related to the negotiated charge paid by the Commodity Credit Corporation for storing CCC-owned grain. The rate during the 1966-67 period was $.00036 per day for commingled grain. This rate yields an annual rate of 13.14 cents per bushel.

This charge includes storage, insuring, conditioning and all other related services except receiving and loading out.

Costs of Milling Wheat Flour

The major operating cost items of flour milling are presented by region in Table XVIII. Total costs varied from a low of $.6209 per hundredweight of product sold in the North Central region to a high of $.9527 in the South Atlantic region. The higher cost in the South Atlantic was due to significantly higher selling expenses, container costs, and miscellaneous expenses. Mills in this region were not specialized in bakery flour to the same extent as were mills in other regions. Consequently, producing and marketing family flour in bags was very likely associated with higher expenses in these categories.

The most important expense item in all regions was manufacturing expenses. This category includes depreciation, insurance, taxes, power, salaries and wages. Mills in the South Central region were lower in this category while mills in the Mountain region were significantly higher than average. Significant variations among regions were present in all cost categories.

The major by-product of flour milling is millfeed. Millfeed was not considered in this study since joint-product processing could not be incorporated in the transhipment model when formulated as a transportation problem. Consequently, it was necessary to adjust the costs of Table XVIII and break out that proportion related to flour since these costs were related to a hundredweight of product sold. A yield factor of 71.58 pounds of flour per hundredweight of wheat was assumed.[30] Given this conversion factor, the cost of milling a bushel equivalent

TABLE XVIII

COSTS OF FLOUR MILLING OPERATIONS EXCLUDING COST OF GRAIN AND FLOUR PURCHASES, PER HUNDREDWEIGHT OF PRODUCT SOLD, U. S. REGIONS, 1964-65 MARKETING YEAR

Cost Item	Region						United States
	Middle Atlantic	South Atlantic	North Central	South Central	Mountain	Pacific	
	Dollars Per Hundredweight						
Manufacturing expense	$.3539	$.3272	$.3374	$.2720	$.3769	$.3465	$.3366
Administrative expense	.1284	.1080	.0899	.0876	.1103	.1357	.1019
Selling expense	.1210	.1998	.0745	.0941	.0732	.0514	.0845
Containers	.0933	.1988	.0842	.1500	.1069	.1204	.1008
Others	.0569	.1189	.0429	.0465	.0468	.0488	.0539
Totals	.7535	.9527	.6289	.6502	.7141	.7028	.6777

Source: National Commission on Food Marketing, Organization and Competition in the Milling and Baking Industries, Technical Study No. 5 (Washington, 1966), pp. 37 and 117.

of flour is 42.95 percent of cost based on a hundredweight of product sales. The estimated total milling cost per bushel in each region was as follows:

Region	Dollars/bushel
Middle Atlantic	$.3237
South Atlantic	.4093
North Central	.2702
South Central	.2793
Mountain	.3067
Pacific	.3019

This method of allocation is based on the proportion of total output represented by the two products.

FOOTNOTES

[1]U. S. Department of Agriculture, _Field and Seed Crops, Production, Farm Use, Sales, Value, By States, 1965-1966_, Statistical Reporting Service Pub. No. CrPr 1 (67) (Washington, May, 1967), pp. 5, 7, 9, 11, 15, and 19.

[2]U. S. Department of Agriculture, _Stocks of Grain in All Positions_, Statistical Reporting Service Pub. No. GrLg 11-1 (1-67) (Washington, January 24, 1967), pp. 4, 6, 8, 10, 14, and 16.

[3]U. S. Department of Agriculture, _Field and Seed Crops, Usual Planting and Harvesting Dates, By States in Principal Producing Areas_, Statistical Reporting Service, Agriculture Handbook No. 283 (Washington, March, 1965), pp. 5, 9, 20-21, 30, 33, 40, and 43.

[4]U. S. Department of Agriculture, _Distribution of the Varieties and Classes of Wheat in United States_, Statistical Reporting Service Stat. Bul. 369 (Washington, 1964), pp. 55-65.

[5]H. Wayne Bitting and Robert O. Rogers, "Utilization of Wheat for Food," _Agricultural Economics Research_, XV (Washington, April, 1963), pp. 66-67.

[6]U. S. Department of Agriculture, _National Food Situation_, Economic Research Service Pub. No. NFS-123 (Washington, February, 1968), p. 16.

[7]U. S. Bureau of the Census, _Current Population Reports, Population Estimates_, Series P-25, Pub. No. 380 (Washington, November 24, 1967), p. 12.

[8]U. S. Treasury Department, _Alcohol and Tobacco Summary Statistics, Fiscal Year 1967_, Internal Revenue Service Pub. 67 (1967) (Washington, 1967), p. 6.

[9]Per capita consumption based on breakdown presented in Bitting and Rogers, p. 62,

[10]U. S. Department of Agriculture, Agricultural Handbook No. 283, pp. 40 and 43.

[11]U. S. Department of Agriculture, _Supplement for 1967 to Livestock-Feed Relationships, 1909-63_, Economic Research Service Stat. Bul. No. 337 (Supp.) (Washington, November, 1967), p. 11. The grain-consuming animal unit series accounts for differences in grain

consumption by various classes of livestock but does not consider the type of feed grain used by each class of livestock.

[12]U. S. Department of Agriculture, Statistical Reporting Service Pub. No. CrPr 1 (67), pp. 5, 7, 9, 11, and 15.

[13]U. S. Department of Agriculture, Feed Statistics Through 1966, Economic Research Service Stat. Bul. No. 410 (Washington, September, 1967), pp. 24-25.

[14]U. S. Department of Agriculture, Crop Production, 1967 Annual Summary, Acreage, Yield, Production, By States, Statistical Reporting Service Pub. No. CrPr 2-1 (67) (Washington, December 19, 1967), p. 48.

[15]U. S. Department of Agriculture, Agricultural Handbook No. 283, pp. 5, 8, 20-21, and 30.

[16]The Northwestern Miller (Minneapolis, September, 1965), pp. 68-80.

[17]U. S. Bureau of the Census, Location of Manufacturing Plants by Industry, County and Employment Size: Part 1, Food and Kindred Products, Special Report No. MC63(S)-3.1 (Washington, 1963), pp. 75-76.

[18]Ibid., p. 94.

[19]Ibid., pp. 72-73.

[20]U. S. Treasury Department, Pub. 67 (1967), pp. 7 and 41.

[21]U. S. Department of Agriculture, Fats and Oil Situation, Economic Research Service Pub. No. FOS-243 (Washington, June, 1968), p. 24.

[22]U. S. Department of Agriculture, Statistical Reporting Service Pub. No. CrPr 1 (67), p. 18.

[23]National Commission on Food Marketing, Organization and Competition in the Milling and Baking Industries, Technical Study No. 5 (Washington, June, 1966), p. 12.

[24]The Northwestern Miller (Minneapolis, September, 1967), pp. 20-71.

[25]U. S. Department of Agriculture, Grain Transportation Statistics for the North Central Region, Agricultural Marketing Service Stat. Bul. No. 268 (Washington, August, 1960), p. 16.

[26]Hoy A. Richards and Jack T. Lamkin, An Empirical Analysis of Motor and Inland Water Carrier Grain Rate Structures for the North Central Region of the United States (unpub. final report on a study conducted by the Texas Transportation Institute in cooperation with the U. S. Department of Agriculture, Economic Research Service, Marketing Economics Division, College Station, April, 1967).

[27]Arrow Transportation Company, Guide to Published Barge Rates on Bulk Grain, Schedule No. 5 (Sheffield, April 12, 1966).

[28]The estimates were based on the data reported in Costs of Storing and Handling Grain in Commercial Elevators, 1964-65, U. S. Department of Agriculture, Economic Research Service Pub. No. 288 (Washington, April, 1966).

[29]U. S. Department of Agriculture, Uniform Grain Storage Agreement, Schedule of Charges, Commodity Credit Corporation Form CCC-25-2 (7-1-66) (Washington, 1966).

[30]Bitting and Rogers, pp. 66-67.

CHAPTER V

ANNUAL ANALYSES

Annual models are useful in studying optimum geographical grain flows, regional flour milling activities, and optimum flour distribution patterns. In addition, useful information can be derived from solutions of these models concerning regional price differentials and the locational advantage of various production and consumption regions as well as marketing firms in those regions. Three annual models were formulated and solved using linear programming techniques. Model I incorporated the basic data (in annual form) as it was presented in Chapter IV. Model II differed from Model I in that regional milling capacities were not restricted to actual levels. Model III incorporated certain assumptions related to stock spreading or minimum regional inventory levels for wheat and feed grain. In addition to the three annual models, a quarterly time-staged model was formulated and its solution is presented in Chapter VI.

Model I

Model I was based on the regional demarcation of Figures 10 and 11 and data on supplies, demands, capacities and marketing costs presented in Chapter IV. Least-cost distribution patterns and intermarket equilibrium price differentials were determined for each grain and grain product simultaneously. Both hard wheat and soft wheat were allowed to compete for the limited flour milling capacity of each region, and the optimum quantities of each milled in the various regions were determined. Each grain also competes for the limited storage space of each region, but the model largely ignores the requirements for storage space since only ending inventories compete for storage. The results of the time-staged model will bring storage requirements into proper perspective since quarterly inventory levels are involved.

Optimum Geographical Flows

The optimum spatial flow patterns for the various grains and flours were derived and are presented in the following sections. These flow patterns should be interpreted as how the marketing system should function given the supply, demand, and competitive conditions of 1966-67 in order to minimize the cost of supplying the estimated regional requirements for grain and flour from the available grain supplies. Given the basic data of Chapter IV, no other flow patterns exist which will result in a lower total cost for the system as a whole. This, of course, assumes that the input data are accurate.

Hard Wheat

The three uses of wheat in the model were flour milling, export and seed. The optimum source of seed in all regions was from local supplies and no interregional movement took place. This resulted primarily from an assumption that seed are needed at wheat origins rather than destinations and only handling costs were incurred in satisfying these requirements from local supplies. The requirements were given in Table VIII.

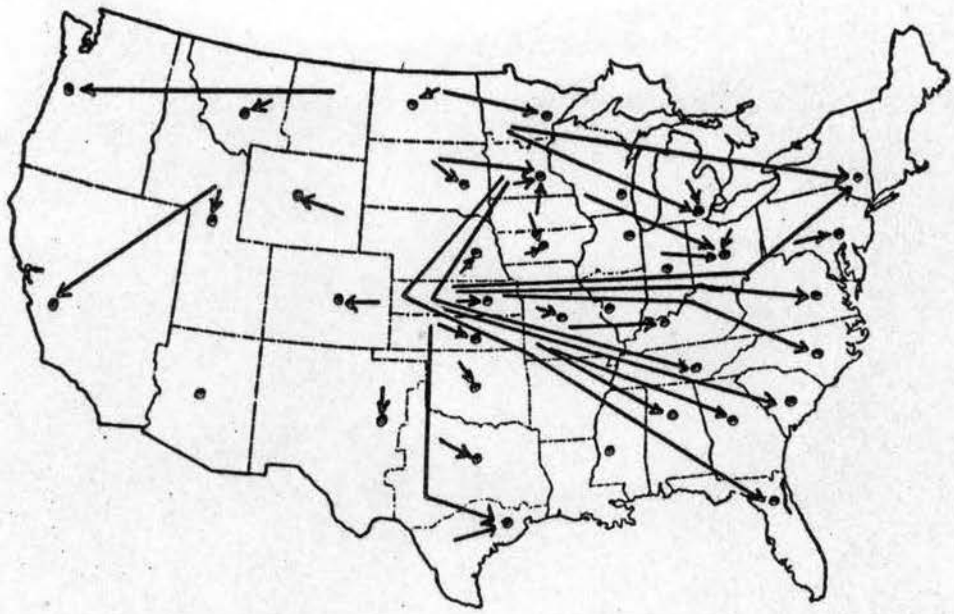
The optimum hard wheat shipments from supply regions to flour mills and to export points are presented in Table XIX. The major inter-regional flows of hard wheat were from the West North Central states to mill points located in Eastern and Southeastern states. Movements to the Southeast came from southern Minnesota, Missouri and northern Kansas, while movements into the Northeast came from northern Minnesota and northern Kansas. The shipments to these regions were mostly combination movements involving either barges and rail or truck. The only major interstate movements in the West were from Idaho-Utah to California and a smaller movement from Montana to Washington-Oregon. The domestic flows are illustrated in Figure 12, Section A.

Exporting firms compete with domestic millers for available supplies of grain, and requirements at ports must be considered simultaneously in determining domestic flows. The requirements at Duluth-Superior (the major hard wheat exit on the Seaway) were satisfied entirely with North Dakota wheat (Table XIX). Favorable lake rates resulted in the supplies of northern Minnesota moving to domestic mills rather than export. Shipments to Duluth-Superior from northern Minnesota rather than North Dakota would have increased the total cost of wheat transportation by about 14 cents for each bushel shipped. The optimum supply sources for Atlantic ports were southern Minnesota, Illinois and Nebraska, and Gulf requirements were satisfied with shipments from Nebraska, southern Kansas, and the West South Central states. Export requirements at Pacific ports were supplied by hard red spring wheat produced in Washington, Idaho, Montana and North Dakota. The export flows are illustrated in Figure 12, Section B.

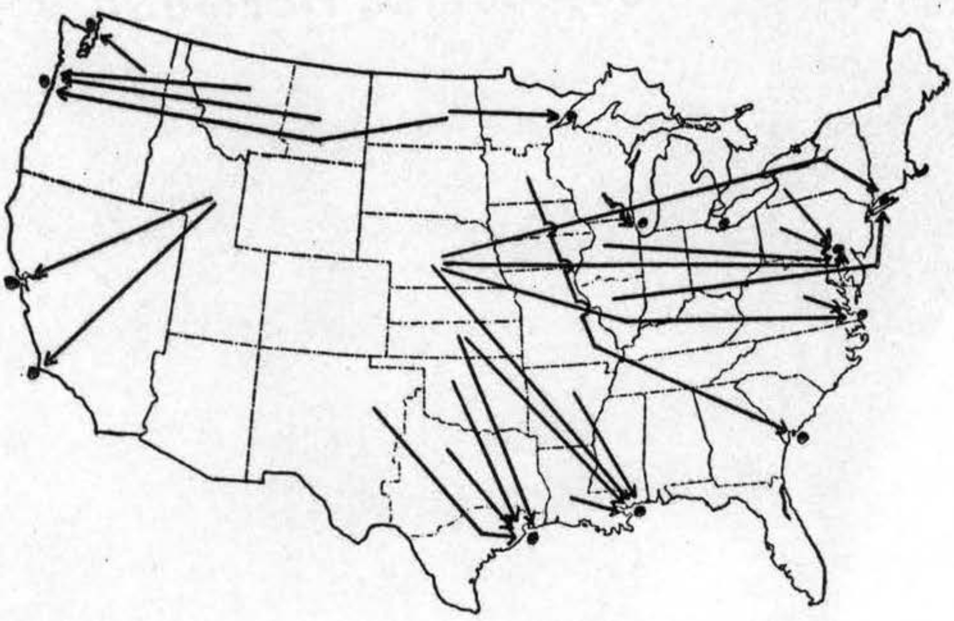
TABLE XIX

OPTIMUM HARD WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL I

Supply Region		Demand Region		Quantity Shipped	Supply Region		Demand Region		Quantity Shipped
				10,000 Bu.					10,000 Bu.
2	N.Y.	47	Balt.	367	17	Neb.	48	Norf.	1,270
3	Pa.	3	Pa.	560			50	N.O.	6,078
		47	Balt.	5	18	Kan.	2	N.Y.	2,672
4	Ohio	4	Ohio	42			18	Kan.	3,432
5	Ind.	4	Ohio	157			20	Va.	205
6	Ill.	6	Ill.	802			21	N.C.	943
		47	Balt.	869			22	S.C.	85
7	Ill.	7	Ill.	1,860	19	Kan.	19	Kan.	4,552
		46	Alb.	561			33	Tex.	182
8	Mich.	8	Mich.	28			50	N.O.	1,901
9	Wisc.	4	Ohio	1,210			51	Hous.	4,150
		44	Chic.	39	20	Va.	48	Norf.	55
10	Minn.	2	N.Y.	1,767	29	Ark.	50	N.O.	121
		8	Mich.	582	30	La.	50	N.O.	85
11	Minn.	11	Minn.	175	31	Okla.	31	Okla.	1,086
		24	Fla.	92			51	Hous.	9,588
		26	Tenn.	1,316	32	Tex.	32	Tex.	64
		49	N.Ch.	151			51	Hous.	6,107
12	Iowa	11	Minn.	228	33	Tex.	33	Tex.	571
		13	Iowa	92	34	Tex.	34	Tex.	2,392
13	Iowa	13	Iowa	422			51	Hous.	970
14	Mo.	14	Mo.	1,981	35	Mont.	41	Wash.	117
		23	Ga.	53			54	Port.	1,352
		25	Ky.	268	36	Mont.	36	Mont.	124
		27	Ala.	238			54	Port.	4,421
15	N.D.	10	Minn.	72	37	Wyo.	37	Wyo.	53
		15	N.D.	364	38	Col.	38	Col.	578
		43	Sup.	1,354	40	Idaho	40	Utah	1,399
		54	Port.	37			42	Cal.	966
16	S.D.	11	Minn.	3,521			52	L.B.	34
		16	S.D.	124			53	Stk.	17
17	Neb.	17	Neb.	1,576	41	Wash.	41	Wash.	1,868
		46	Alb.	254			55	Seat.	1,289
		47	Balt.	2,387	42	Cal.	42	Cal.	70



Section A. Domestic Flows



Section B. Export Flows

Figure 12. Optimum Flow Patterns for Hard-Wheat, Model I

Hard-Wheat Flour

Optimum geographical flows of hard-wheat flour from mills were determined simultaneously with the flows of hard wheat to mills presented above. Since no allowance was made for flour storage in the model, the volume of flour shipped from mills in a particular region was equivalent to the volume of wheat received at mills in that region. Thus, wheat was not milled into flour unless the flour was needed to satisfy regional demands.

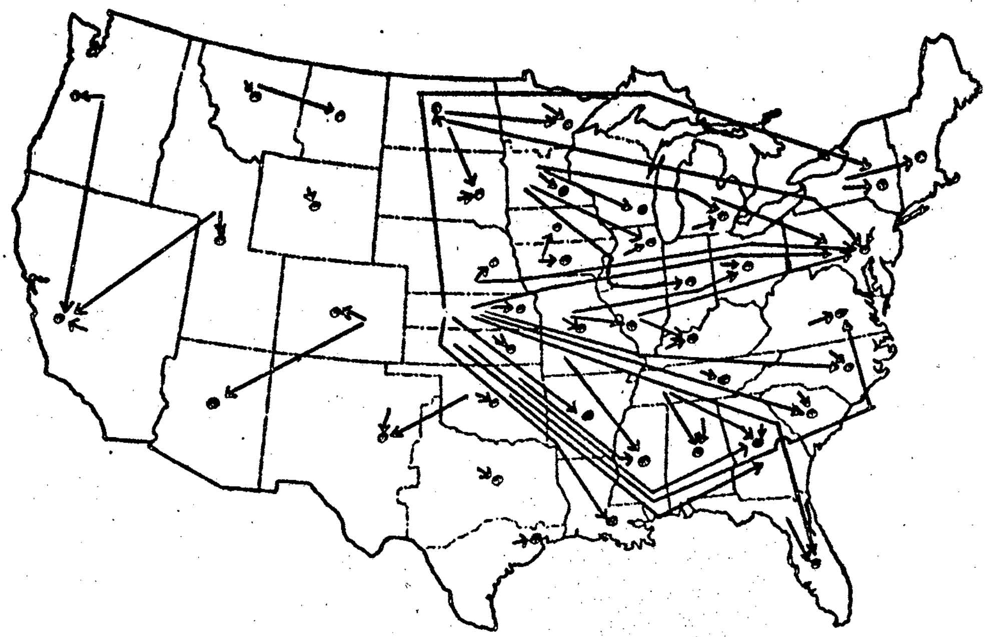
The predominant flow of hard-wheat flour from mills to domestic demands was from the North Central states to demand points in the Northeast and South Atlantic regions (Table XX and Figure 13, Section A). Significant flows to California also occurred from Washington-Oregon and Idaho-Utah. Nineteen of the 37 milling regions milled hard-wheat flour for consumption in other regions. The most important regions by far in terms of hard-wheat flour production for interregional shipments were the two Kansas regions, and the combined grind for out-of-state shipment was approximately 75 million bushels. Southern Minnesota mills were next with a grind of about 34 million bushels bound for out-of-state destinations. New York mills ground in excess of 44 million bushels of hard wheat, but approximately 60 percent of this total was consumed within the state with the balance shipped to New England. Other regions milling in excess of 10 million bushels for interregional shipment were southern Illinois, Missouri, Nebraska, east Texas, Utah-Idaho, and Washington-Oregon.

It is evident from Table XX that a great proportion of hard-wheat flour was milled near wheat origins or at flour destinations and that it was biased toward hard wheat origins because of the existing

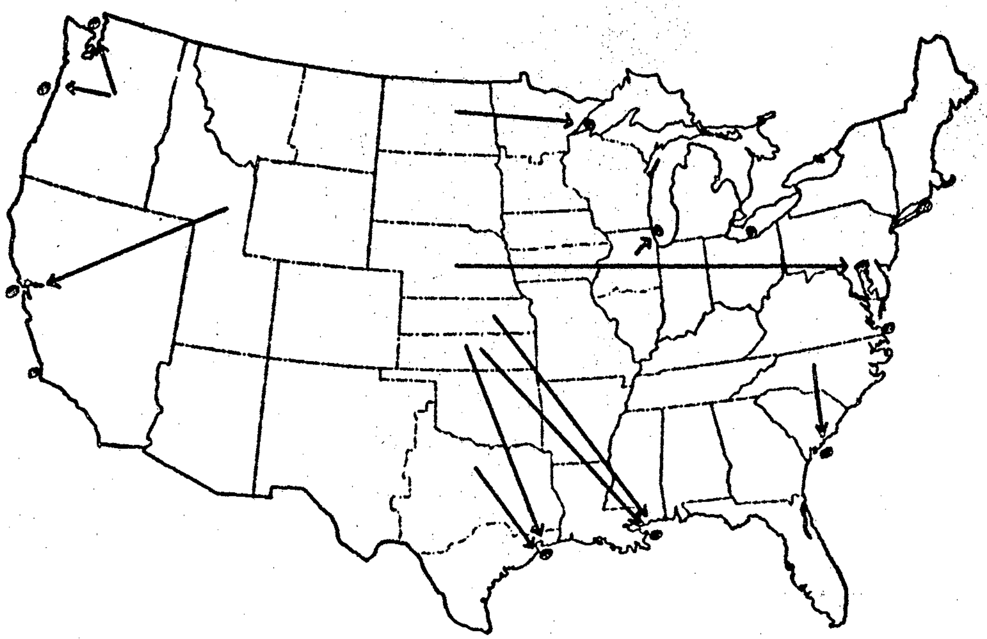
TABLE XX

OPTIMUM HARD-WHEAT FLOUR SHIPMENTS FROM MILLING REGIONS TO DEMAND REGIONS (WHEAT EQUIVALENTS), MODEL I

Milling Region	Demand Region	Quantity Shipped	Milling Region	Demand Region	Quantity Shipped
		10,000 Bu.			10,000 Bu.
2 N.Y.	1 N.E.	1,696	19 Kan.	2 N.Y.	46
	2 N.Y.	2,743		19 Kan.	267
3 Pa.	3 Pa.	560		20 Va.	995
4 Ohio	4 Ohio	1,409		23 Ga.	450
6 Ill.	6 Ill.	768		50 N.O.	1,001
	44 Chic.	34		51 Hous.	1,793
7 Ill.	3 Pa.	1,510	20 Va.	20 Va.	205
	25 Ky.	350	21 N.C.	21 N.C.	904
8 Mich.	3 Pa.	58		49 N.Ch.	39
	8 Mich.	552	22 S.C.	22 S.C.	85
10 Minn.	10 Minn.	72	23 Ga.	23 Ga.	53
11 Minn.	5 Ind.	893	24 Fla.	24 Fla.	92
	6 Ill.	760	25 Ky.	25 Ky.	268
	8 Mich.	1,003	26 Tenn.	23 Ga.	191
	9 Wisc.	768		26 Tenn.	715
	11 Minn.	500		27 Ala.	410
13 Iowa	12 Iowa	195	27 Ala.	27 Ala.	238
	13 Iowa	319	31 Okla.	23 Ga.	117
14 Mo.	4 Ohio	460		28 Miss.	183
	7 Ill.	439		31 Okla.	453
	14 Mo.	814		32 Tex.	333
	28 Miss.	268	32 Tex.	32 Tex.	64
15 N.D.	3 Pa.	140	33 Tex.	33 Tex.	753
	10 Minn.	75	34 Tex.	34 Tex.	989
	15 N.D.	120		51 Hous.	1,403
	16 S.D.	2	36 Mont.	35 Mont.	41
	43 Dul-S.	27		36 Mont.	83
16 S.D.	16 S.D.	124	37 Wyo.	37 Wyo.	53
17 Neb.	3 Pa.	1,124	38 Col.	38 Col.	320
	17 Neb.	271		39 Ariz.	258
	47 Balt.	181	40 Utah	40 Utah	291
18 Kan.	3 Pa.	385		42 Cal.	1,074
	18 Kan.	267		53 S.F.	34
	21 N.C.	32	41 Wash.	41 Wash.	847
	22 S.C.	410		42 Cal.	928
	24 Fla.	952		54 Port.	123
	29 Ark.	363		55 Seat.	87
	30 La.	657	42 Cal.	42 Cal.	1,036
	50 N.O.	366			



Section A. Domestic Flows



Section B. Export Flows

Figure 13. Optimum Flow Patterns for Hard-Wheat Flour, Model I

geographical distribution of milling capacity. However, three milling regions, namely New York, southern Minnesota, and Tennessee, were striking examples of transhipment points for milling where the milling was performed between the wheat supply regions and flour demand centers. The New York mills received wheat from Minnesota and Kansas and sold flour in New England. The southern Minnesota mills procured wheat from South Dakota and Iowa, as well as locally, and shipped flour to Indiana, Illinois, Michigan and Wisconsin. Tennessee millers procured wheat from southern Minnesota and shipped flour to Alabama and Georgia.

The major ports of exit for hard-wheat flour moving to export markets were New Orleans and Houston with smaller volumes exported through other ports. The major flows to Gulf ports originated in eastern Texas and southern Kansas (Table XX). Export outlets were important markets for mills in these regions and they shipped approximately 60 percent of their annual flour outputs to Gulf export points. Other regions involved on a smaller scale in the export flour trade were Illinois, North Dakota, North Carolina, Utah-Idaho, and Washington-Oregon. The flows to ports are illustrated in Figure 13, Section B.

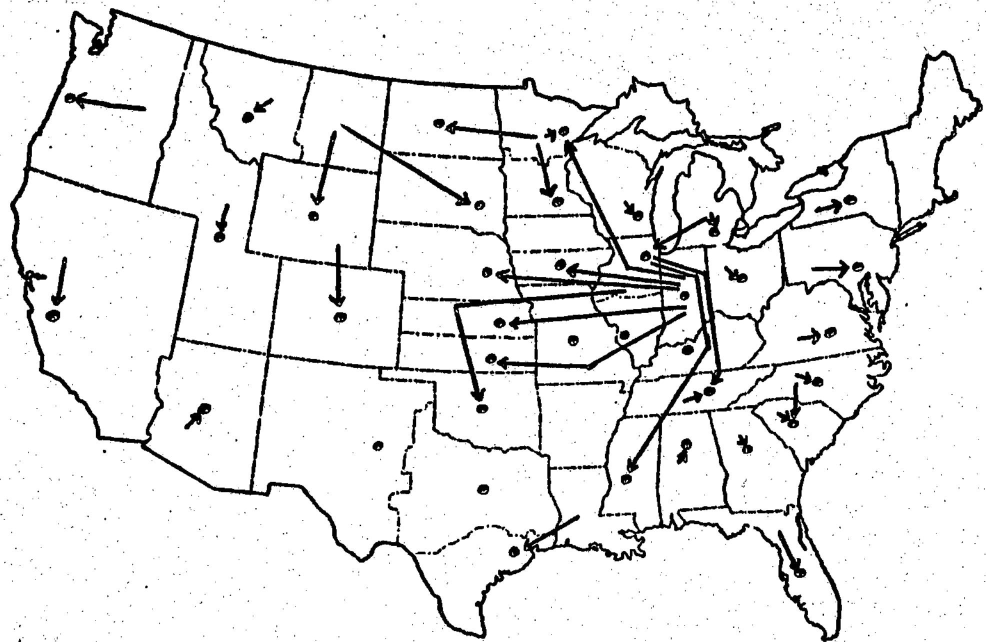
Soft Wheat

As was the case for hard wheat, regional soft wheat seed requirements were satisfied entirely from local supplies. Regional use of soft-wheat flour was less than half that of hard-wheat flour, and interregional movements of soft wheat to mills (Table XXI) were correspondingly smaller than those of hard wheat. The major flows were from the East North Central states to West North Central states, and most of these shipments originated in Indiana (see Figure 14). Mills in 21

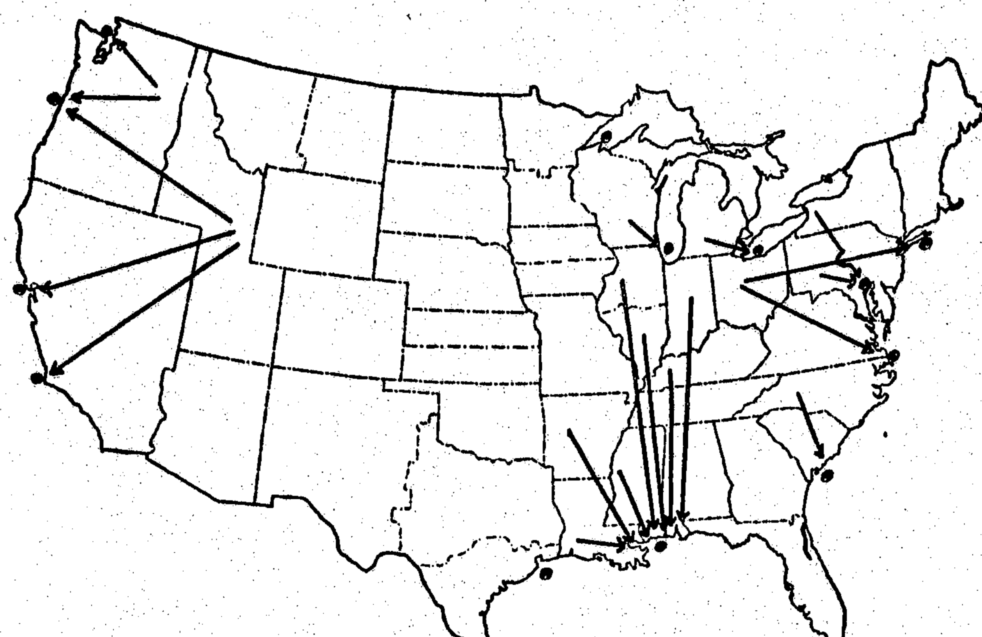
TABLE XXI

OPTIMUM SOFT WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL I

Supply Region		Demand Region		Quantity Shipped	Supply Region		Demand Region		Quantity Shipped
				10,000 Bu.					10,000 Bu.
2	N.Y.	2	N.Y.	1,157	20	Va.	20	Va.	467
		47	Balt.	953	21	N.C.	21	N.C.	373
3	Pa.	3	Pa.	1,448			22	S.C.	24
		47	Balt.	170			49	N.Ch.	15
4	Ohio	4	Ohio	2,215	22	S.C.	22	S.C.	163
		46	Alb.	364	23	Ga.	23	Ga.	175
		48	Norf.	747	24	Fla.	24	Fla.	56
5	Ind.	5	Ind.	1,660	25	Ky.	50	N.O.	511
		10	Minn.	36	26	Tenn.	26	Tenn.	396
		13	Iowa	128	27	Ala.	27	Ala.	146
		17	Neb.	104	28	Miss.	50	N.O.	664
		18	Kan.	120	29	Ark.	50	N.O.	911
		19	Kan.	80	30	La.	33	Tex.	99
		50	N.O.	191			50	N.O.	81
6	Ill.	26	Tenn.	32	35	Mont.	16	S.D.	52
		28	Miss.	24			37	Wyo.	107
		31	Okla.	164	36	Mont.	36	Mont.	52
		50	N.O.	408	37	Wyo.	38	Col.	13
7	Ill.	50	N.O.	1,274	39	Ariz.	39	Ariz.	48
8	Mich.	6	Ill.	474	40	Idaho	40	Utah	201
		8	Mich.	1,162			52	L.B.	8
		45	Tol.	1,308			53	Stk.	12
9	Wisc.	9	Wisc.	8			54	Port.	82
		44	Chic.	97	41	Wash.	41	Wash.	707
10	Minn.	10	Minn.	20			54	Port.	9,223
		11	Minn.	192			55	Seat.	2,354
		15	N.D.	48	42	Cal.	42	Cal.	1,048
14	Mo.	14	Mo.	2,125					



Section A. Domestic Flows



Section B. Export Flows

Figure 14. Optimum Flow Patterns for Soft-Wheat, Model I

regions obtained wheat from local supplies only, and this greatly reduced the interregional activity.

Export requirements at Lake ports were satisfied entirely from nearby supplies. The most important movement was shipments of about 13 million bushels from Michigan to Toledo (Table XXI). Requirements at major Atlantic ports were satisfied with shipments from Ohio and states farther east. Shipments to New Orleans originated in several regions located adjacent to the Mississippi-Ohio river system. Pacific ports drew over 99 percent of requirements from the Washington-Oregon region, and about one million bushels were shipped from Idaho. The flow pattern is illustrated in Figure 14.

Soft-Wheat Flour

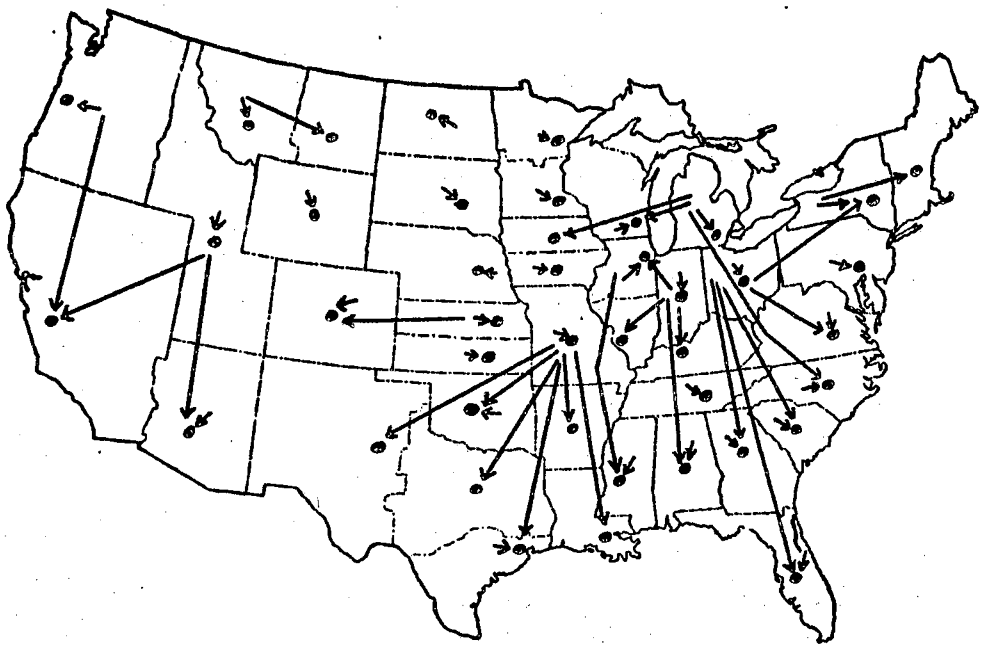
About 150 million bushels of soft wheat were milled into flour to satisfy domestic requirements. Even though much more hard wheat flour is produced in the United States, soft-wheat flour is the most important type of flour produced in many milling regions, and many mills specialize in soft flour. The optimum shipments of soft flour from flour mills to domestic and export markets are presented in Table XXII and illustrated in Figure 15.

Eleven of the 37 milling regions milled soft-wheat flour for consumption in other regions. The milling regions most heavily involved in interregional trade were New York, Ohio, Indiana, Missouri and Michigan; and Ohio, Indiana and Missouri milled in excess of 13 million bushels for out-of-state consumption. Illinois and Washington were the only other states having out-of-state soft-wheat flour markets demanding the flour equivalent of one million bushels or more.

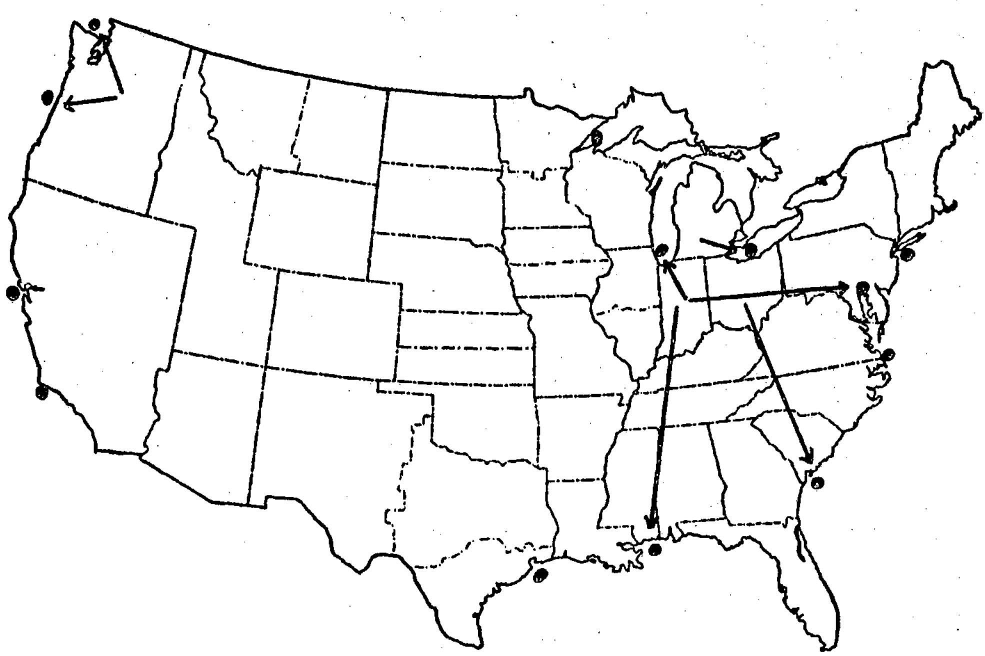
TABLE XXII

OPTIMUM SOFT-WHEAT FLOUR SHIPMENTS FROM MILLING REGIONS TO DEMAND REGIONS (WHEAT EQUIVALENTS), MODEL I

Milling Region	Demand Region	Quantity Shipped	Milling Region	Demand Region	Quantity Shipped
		10,000 Bu.			10,000 Bu.
2 N.Y.	1 N.E.	560	14 Mo.	32 Tex.	204
	2 N.Y.	597		33 Tex.	333
3 Pa.	3 Pa.	1,448		34 Tex	568
4 Ohio	2 N.Y.	323	15 N.D.	15 N.D.	48
	4 Ohio	696	16 S.D.	16 S.D.	52
	20 Va.	241	17 Neb.	17 Neb.	104
	22 S.C.	109	18 Kan.	18 Kan.	80
	23 Ga.	305		38 Col.	40
	24 Fla.	528	19 Kan.	19 Kan.	80
	49 N.Ch.	13	20 Va.	20 Va.	467
5 Ind.	5 Ind.	340	21 N.C.	21 N.C.	373
	6 Ill.	354	22 S.C.	22 S.C.	187
	7 Ill.	160	23 Ga.	23 Ga.	175
	25 Ky.	376	24 Fla.	24 Fla.	56
	27 Ala.	246	26 Tenn.	26 Tenn.	428
	44 Chic.	18	27 Ala.	27 Ala.	146
	47 Balt.	79	28 Miss.	28 Miss.	24
	50 N.O.	87	31 Okla.	31 Okla.	164
6 Ill.	6 Ill.	210	33 Tex.	33 Tex.	99
	28 Miss.	264	36 Mont.	35 Mont.	16
8 Mich.	8 Mich.	576		36 Mont.	36
	9 Wisc.	288	37 Wyo.	37 Wyo.	24
	12 Iowa	80		38 Col.	83
	21 N.C.	195	38 Col.	38 Col.	13
	45 Tol.	23	39 Ariz.	39 Ariz.	48
9 Wisc.	9 Wisc.	8	40 Utah	39 Ariz.	60
10 Minn.	10 Minn.	56		40 Utah	128
11 Minn.	11 Minn.	192		42 Cal.	13
13 Iowa	13 Iowa	128	41 Wash.	41 Wash.	364
14 Mo.	14 Mo.	312		42 Cal.	223
	29 Ark.	224		54 Port.	82
	30 La.	384		55 Seat.	38
	31 Okla.	100	42 Cal.	42 Cal.	1,048



Section A. Domestic Flows



Section B. Export Flows

Figure 15. Optimum Flow Patterns for Soft-Wheat Flour, Model I

Soft-wheat flour exports were very small and accounted for an estimated six to seven percent of total flour exports. Requirements at Lake ports were supplied by Indiana and Michigan, and Ohio and Indiana shipped soft flour to Atlantic ports. New Orleans requirements were supplied by Indiana millers, and the soft flour exported from the Pacific ports was milled in Washington.

Durum Wheat

Durum wheat movements were very limited compared with hard and soft wheat movements. The domestic demands for durum in each region included requirements for processing and for seed. The only interstate movements to domestic demands were shipments between Minnesota and mill locations in Wisconsin and New York, and shipments to Washington mills from Montana (Table XXIII).

The major port of exit for durum exports was Duluth-Superior and the requirements at this port were satisfied with shipments from North Dakota (Table XXIII). Quantities exported through Atlantic ports were shipped from southern Minnesota and South Dakota. Southern Minnesota also supplied the needs of Gulf ports, and export requirements at Portland, Oregon, came from Montana and California. Domestic and export flow patterns for durum wheat are shown in Figure 16.

Feed Grain

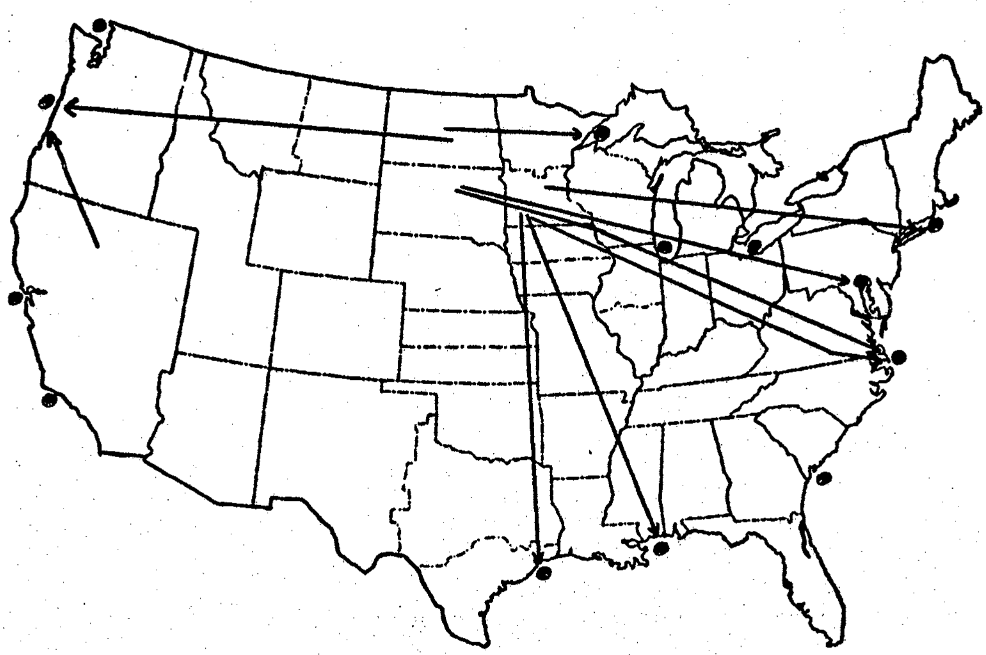
The volume of feed grain produced and marketed was larger than for the other grains included in the study, and greater interregional movements were present. The optimum or least-cost distribution pattern for feed grain is presented in Table XXIV. The large interregional

TABLE XXIII

OPTIMUM DURUM WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL I

Supply Region		Demand Region		Quantity Shipped	Supply Region		Demand Region		Quantity Shipped
				10,000 Bu.					10,000 Bu.
10	Minn.	2	N.Y.	240	15	N.D.	43	Sup.	2,749
		9	Wisc.	508	16	S.D.	16	S.D.	20
		10	Minn.	11			47	Balt.	289
		11	Minn.	927			48	Norf.	107
11	Minn.	11	Minn.	9	35	Mont.	35	Mont.	12
		46	Alb.	83			41	Wash.	141
		48	Norf.	709			54	Port.	22
		50	N.O.	729	36	Mont.	36	Mont.	8
		51	Hous.	70			41	Wash.	223
15	N.D.	15	N.D.	537	42	Cal.	54	Port.	30

Section A. Domestic Flows



Section B. Export Flows

Figure 16. Optimum Flow Patterns for Durum Wheat, Model I

TABLE XXIV

OPTIMUM FEED GRAIN SHIPMENTS FROM SUPPLY REGIONS TO DOMESTIC DEMAND REGIONS, MODEL I

Supply Region	Demand Region	Quantity Shipped	Supply Region	Demand Region	Quantity Shipped
		10,000 Bu.			10,000 Bu.
1 N.E.	1 N.E.	213	16 S.D.	16 S.D.	1,077
2 N.Y.	2 N.Y.	1,618	17 Neb.	17 Neb.	7,698
3 Pa.	3 Pa.	4,669		38 Col.	58
4 Ohio	3 Pa.	10,526		42 Cal.	9,268
	4 Ohio	2,498	18 Kan.	18 Kan.	1,916
	20 Va.	4,413	19 Kan.	19 Kan.	941
5 Ind.	1 N.E.	8,820		29 Ark.	2,453
	2 N.Y.	6,777		31 Okla.	3,677
	3 Pa.	3,153	20 Va.	20 Va.	1,125
	5 Ind.	7,623	21 N.C.	21 N.C.	3,935
6 Ill.	23 Ga.	14,657	22 S.C.	22 S.C.	931
	24 Fla.	379	23 Ga.	23 Ga.	3,533
	27 Ala.	6,105	24 Fla.	24 Fla.	693
	28 Miss.	626	25 Ky.	25 Ky.	2,957
7 Ill.	20 Va.	1,130	26 Tenn.	26 Tenn.	1,782
	21 N.C.	9,544	27 Ala.	27 Ala.	1,136
	22 S.C.	2,014	28 Miss.	28 Miss.	608
	27 Ala.	5,199	29 Ark.	29 Ark.	740
8 Mich.	3 Pa.	281	30 La.	30 La.	844
	8 Mich.	3,472	31 Okla.	29 Ark.	3,041
9 Wisc.	9 Wisc.	6,052	32 Tex.	32 Tex.	2,676
11 Minn.	30 La.	1,791	33 Tex.	33 Tex.	5,147
12 Iowa	6 Ill.	8,775	34 Tex.	28 Miss.	7,220
	12 Iowa	2,751		34 Tex.	7,837
	26 Tenn.	6,434	35 Mont.	35 Mont.	143
13 Iowa	6 Ill.	2,348		36 Mont.	294
	7 Ill.	7,772		37 Wyo.	175
	13 Iowa	12,127		41 Wash.	1,156
	14 Mo.	13,204	36 Mont.	40 Utah	273
	24 Fla.	2,778	37 Wyo.	38 Col.	272
14 Mo.	25 Ky.	2,601	38 Col.	38 Col.	3,082
	27 Ala.	140	39 Ariz.	39 Ariz.	1,355
	29 Ark.	7,892	40 Idaho	40 Utah	2,194
15 N.D.	11 Minn.	8,251[a]	41 Wash.	41 Wash.	4,559
	11 Minn.	2,068	42 Cal.	42 Cal.	11,476
	15 N.D.	16			

[a]These quantities were transhipped through the demand region receiving these shipments.

shipments for the most part originated in the North Central region. The Northeastern states (regions 1-3) satisfied their deficits with shipments from Ohio, Indiana and Michigan. The only interregional flows from these states not moving to the Northeastern states were shipments of about 44 million bushels from Ohio to the Virginia-West Virginia region. With the exception of this movement and shipments of 28 million bushels from Iowa to Florida, deficits in the South Atlantic states (regions 20-24) were satisfied with shipments from Illinois.

The broiler producing states of the South Central region procured feed grain from several origins. Kentucky received feed grain from Missouri; Tennessee from northern Iowa; Alabama from southern Illinois; Mississippi from Missouri and Texas; Arkansas from Iowa, Missouri, southern Kansas, and Oklahoma; Oklahoma from southern Kansas; and Louisiana from southern Minnesota. Deficits in Pacific Coast states were satisfied with shipments from Nebraska and Montana. In general, the predominant direction of flow was an east-southeast direction (Figure 17).

The flow patterns discussed above illustrate the major difference between a transhipment model and a traditional surplus-deficit transportation model. Several states such as Illinois, Missouri, Oklahoma, and Wyoming were involved with both receipts and shipments in interregional competition. Such activity was more pronounced in the quarterly analysis to be discussed later where storage capacity restrictions influenced the timeliness of interregional transfers.

It should be noted that the flow pattern which minimizes the costs for the industry does not always show a particular regional demand being satisfied from origins that would result in the lowest

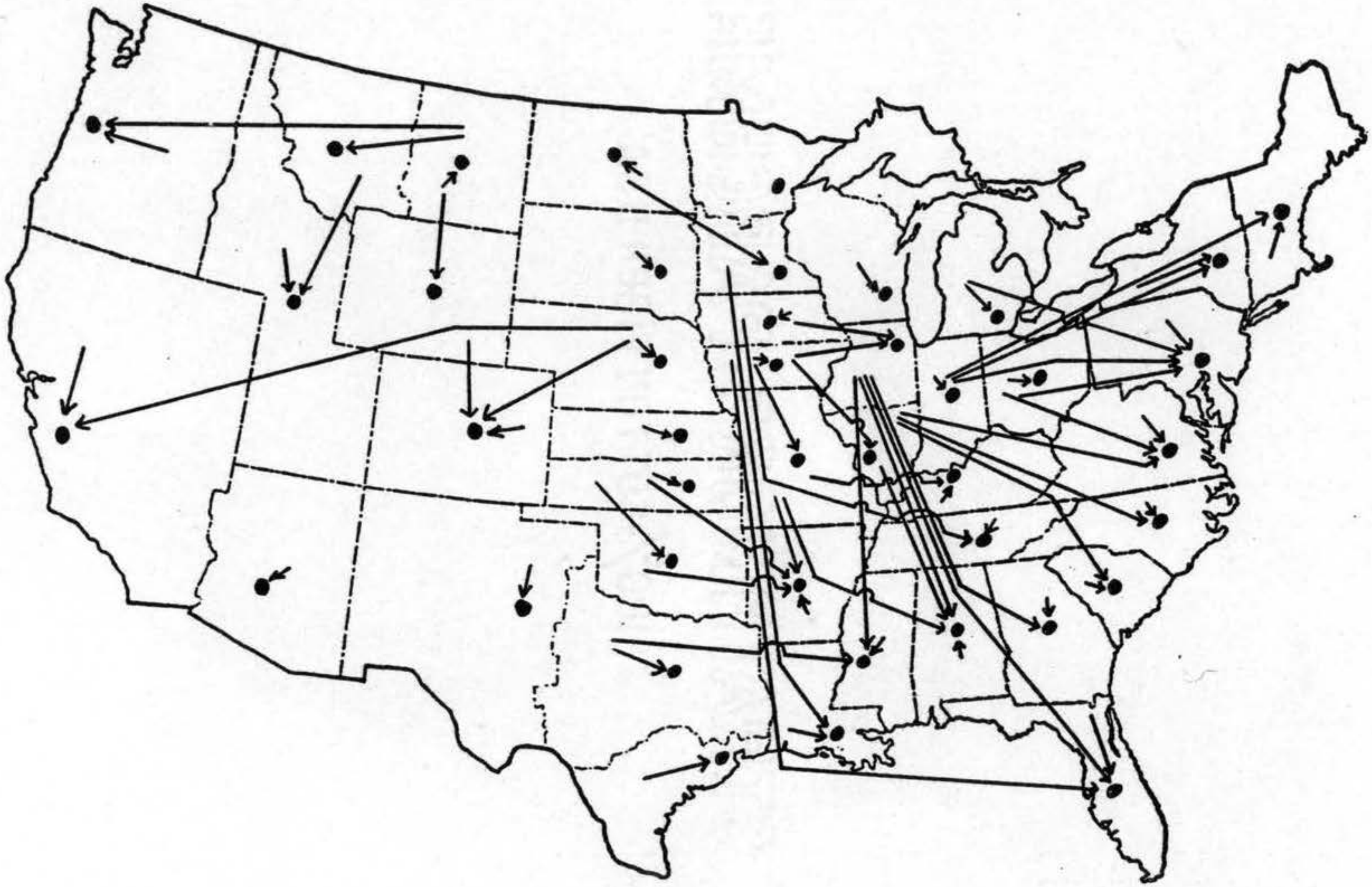


Figure 17. Optimum Flow Pattern for Feed Grain to Domestic Destinations, Model I

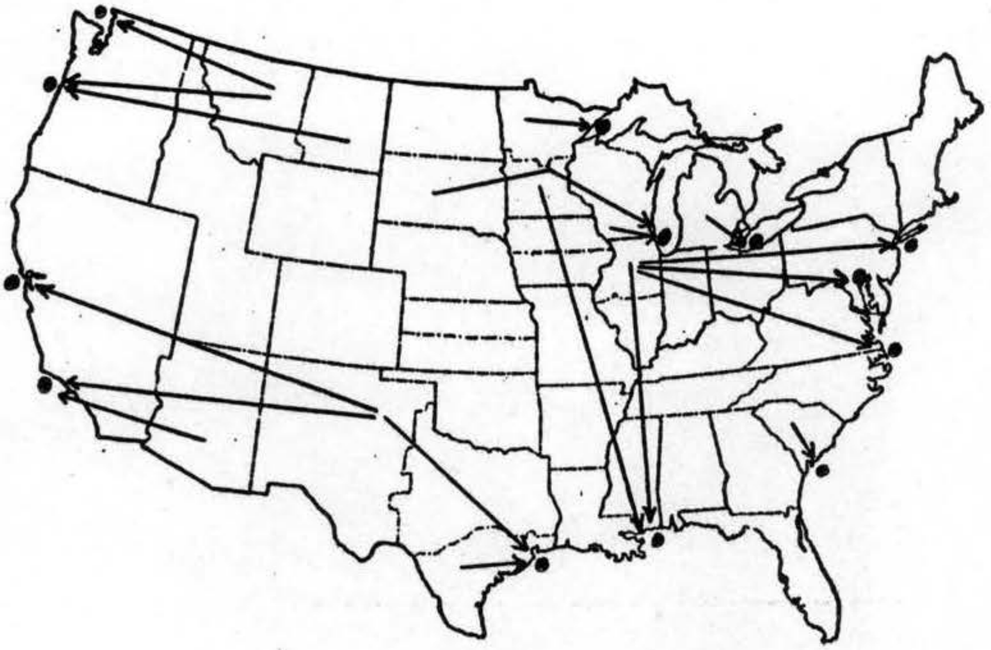
transportation costs to that destination. For example, grain marketed in Oklahoma was shipped to Arkansas while Oklahoma's needs were supplied from Kansas, and Kansas also shipped grain to Arkansas. If Oklahoma feed grain had been shipped to the Oklahoma destination and shipments from Kansas to Arkansas were increased by this amount, the transportation costs associated with supplying Oklahoma's needs would be reduced by $580,831. However, the transportation costs associated with supplying Arkansas' needs would increase by $830,193 resulting in a net increase in total transfer costs of $249,362. Since Kansas would ship feed grain to both Oklahoma and Arkansas destinations in either situation, market prices would not be affected in either region, and the increase in total marketing cost would be reflected in a lower price at the Oklahoma origin (the price would decrease by .82 cents per bushel).

The least-cost shipping pattern for feed grain exported from the United States is given in Table XXV and illustrated in Figure 18. Exports through the Seaway were drawn from adjoining regions except for 41 million bushels shipped to Chicago from South Dakota. The major Atlantic ports were supplied by northern Illinois, and feed grain exported from New Orleans was shipped from southern Minnesota, northern Illinois, and Missouri. Texas ports drew the largest volume from western Texas with smaller volumes moving from southern Texas. The least-cost sources of supply for California ports were western Texas-New Mexico and Arizona, and the optimum source of supply for north Pacific ports was Montana.

TABLE XXV

OPTIMUM FEED GRAIN AND SOYBEAN SHIPMENTS FROM SUPPLY REGIONS TO EXPORT DEMAND REGIONS, MODEL I

Feed Grain					Soybeans				
Supply Region		Demand Region		Quantity Shipped	Supply Region		Demand Region		Quantity Shipped
				10,000 Bu.					10,000 Bu.
6	Ill.	46	Alb.	396	2	N.Y.	45	Tol.	3
		47	Balt.	2,649	3	Pa.	47	Balt.	537
		48	Norf.	2,018	4	Ohio	45	Tol.	1,420
		50	N.O.	19,941			47	Balt.	40
8	Mich.	45	Tol.	2,146	5	Ind.	44	Chic.	1,571
9	Wisc.	44	Chic.	1,495	6	Ill.	50	N.O.	37
10	Minn.	43	Sup.	6,568	7	Ill.	50	N.O.	5,175
11	Minn.	50	N.O.	17,890	8	Mich.	45	Tol.	1,041
16	N.D.	44	Chic.	4,161	9	Wisc.	44	Chic.	314
22	S.C.	49	N.Ch.	40	11	Minn.	43	Sup.	837
32	Tex.	51	Hous.	15,609	21	N.C.	48	Norf.	428
		52	L.B.	3,052	22	S.C.	49	N.Ch.	872
		53	Stk.	924	23	Ga.	50	N.O.	592
33	Tex.	51	Hous.	3,581	24	Fla.	50	N.O.	197
35	Mont.	54	Port.	120	28	Miss.	50	N.O.	3,555
36	Mont.	54	Port.	1,420	29	Ark.	50	N.O.	5,739
		55	Seat.	278	30	La.	50	N.O.	2,348
39	Ariz.	52	L.B.	1,132			51	Hous.	11
					31	Okla.	51	Hous.	111
					33	Tex.	51	Hous.	3
					34	Tex.	51	Hous.	21



Section A. Feed Grain Flows

Section B. Soybean Flows

Figure 18. Optimum Flow Patterns for Feed Grain and Soybeans to Port Destinations, Model I

Soybeans

Soybean shipments to domestic demands were aggregated on the basis of Census regions for presentation because regional soybean crushing capacity and volumes crushed were confidential. The data are presented in Table XXVI. Since most soybean production regions also have crushing plants, a great deal of interregional movement between origins and processing plants was not expected. The only census regions receiving imports of soybeans in the analysis of Model I were the East North Central and East South Central regions, and these flows were generally confined to adjoining states.

The optimum flows of soybeans to ports are presented in Table XXV. Requirements at the Lake and Atlantic ports generally were drawn from nearby origins. Requirements at Gulf ports were supplied by several regions, and large quantities were shipped by barge to New Orleans from regions adjacent to the Mississippi River system (Figure 18).

Optimum Utilization of Milling Capacity

Optimum utilization of milling capacity is used in this study to refer to the specification of both the type and the volume of wheat that should be milled in each region in order to minimize total marketing cost. This information was determined simultaneously with the optimum geographical flows of wheat and flour in the model.

The volume of each type of wheat milled, the unused milling capacity, and the value of additional milling capacity in each milling region are presented in Table XXVII. The information indicates that mills in New York processed about 44 million bushels of hard wheat and about 12 million bushels of soft wheat. These volumes fully utilized

TABLE XXVI

OPTIMUM SOYBEAN SHIPMENTS FROM SUPPLY REGIONS TO DOMESTIC DEMAND REGIONS, MODEL I

	Destination[a]				
Origin[a]	South Atlantic	East North Central	West North Central	East South Central	West South Central
	10,000 Bu.				
South Atlantic	3,468	0	0	93	0
East North Central	0	22,131	0	0	0
West North Central	0	1,811	18,849	0	0
East South Central	0	0	0	5,601	0
West South Central	0	0	0	211	3,794

[a]Individual shipments were aggregated to standard regions used by the Bureau of the Census to avoid disclosure of individual firm capacities.

TABLE XXVII

OPTIMUM UTILIZATION OF EXISTING FLOUR MILLING CAPACITY, UNUSED MILLING CAPACITY, AND VALUE OF ADDITIONAL CAPACITY, MODEL I

Milling Region		Quantity of Hard Wheat Milled	Quantity of Soft Wheat Milled	Unused Milling Capacity	Value of Additional Capacity
		10,000 Bu.	10,000 Bu.	10,000 Bu./Yr.	$/10,000 Bu.
2	N.Y.	4,439	1,157	0	894
3	Pa.	560	1,448	0	887
4	Ohio	1,409	2,215	0	382
5	Ind.	0	1,660	0	332
6	Ill.	802	474	0	816
7	Ill.	1,860	0	0	361
8	Mich.	610	1,162	0	644
9	Wisc.	0	8	0	1,783
10	Minn.	72	56	0	406
11	Minn.	3,924	192	0	167
13	Iowa	514	128	582	0
14	Mo.	1,981	2,125	874	0
15	N.D.	364	48	0	251
16	S.D.	124	52	0	2,436
17	Neb.	1,576	104	0	977
18	Kan.	3,432	120	0	198
19	Kan.	4,552	80	0	691
20	Va.	205	467	0	581
21	N.C.	943	373	0	751
22	S.C.	85	187	0	1,727
23	Ga.	53	175	0	1,162
24	Fla.	92	56	0	2,472
25	Ky.	268	0	0	2,266
26	Tenn.	1,316	428	0	1,341
27	Ala.	283	146	0	3,102
28	Miss.	0	24	0	2,727
31	Okla.	1,086	164	482	0
32	Tex.	64	0	0	1,852
33	Tex.	753	99	0	998
34	Tex.	2,392	0	0	225
36	Mont.	124	52	424	0
37	Wyo.	53	107	0	1,503
38	Col.	578	13	113	0
39	Ariz.	0	48	0	5,053
40	Utah	1,399	201	0	1,817
41	Wash.	1,985	707	420	0
42	Cal.	1,036	1,048	0	1,295

the milling capacity of New York, and the value of capacity to mill an additional 10,000 bushels was $894. This value of additional capacity is a marginal figure and was applicable only if capacity in New York had been expanded while milling capacity in other regions had been constrained at existing levels. The relative importance of this marginal value figure can be illustrated by considering that gross sales of products by flour millers averaged $4.96 per hundredweight during 1964-65.[1] The $894 figure for New York would be about 4% of gross sales. The relative level of these data for the various regions is an estimate of the relative profitability of flour mill operations in the regions. In general, the data suggest that flour milling was more profitable in Southeastern states than in North Central States where over half of the flour milling capacity is located.

Six of the 37 milling regions had excess milling capacity, and additional capacity was of no value in those regions (Table XXVII). Unused capacity in total is over-estimated somewhat since flour exports designated for relief were excluded from flour export data.

Optimum Ending Inventories of Grain

Once the estimated domestic and export requirements were satisfied, any supplies in excess of these demands moved into storage and showed up as stocks or ending inventories in the model. The inventories by type of grain are presented in Table XXVIII. Hard wheat stocks were located in the West North Central region and in the Mountain states. Soft wheat stocks were located in the East North Central and Mountain regions. Stocks of other grains were generally confined to the West North Central region with the exception of Ohio, Texas and Montana.

TABLE XXVIII

OPTIMUM REGIONAL ENDING INVENTORIES OF GRAIN, MODEL I

Storage Region		Hard Wheat	Soft Wheat	Durum Wheat	Feed Grain	Soy-beans
				10,000 Bu.		
1	N.E.	0	0	0	0	0
2	N.Y.	0	0	0	0	0
3	Pa.	0	251	0	0	0
4	Ohio	0	851	0	0	1,218
5	Ind.	0	1,395	0	0	0
6	Ill.	0	0	0	0	0
7	Ill.	0	0	0	0	0
8	Mich.	0	0	0	0	0
9	Wisc.	0	369	0	0	0
10	Minn.	0	0	41	3,450	2,016
11	Minn.	0	0	0	0	2,071
12	Iowa	0	0	0	0	3,589
13	Iowa	0	0	0	0	2,757
14	Mo.	0	0	0	0	4,379
15	N.D.	11,214	0	3,063	2,715	497
16	S.D.	2,358	0	0	6,453	653
17	Neb.	0	0	0	30,875	2,051
18	Kan.	6,434	0	0	10,303	291
19	Kan.	2,985	0	0	854	0
20	Va.	0	0	0	0	0
21	N.C.	0	0	0	0	0
22	S.C.	0	0	0	0	0
23	Ga.	0	0	0	0	0
24	Fla.	0	0	0	0	0
25	Ky.	0	0	0	0	0
26	Tenn.	0	0	0	0	0
27	Ala.	0	0	0	0	0
28	Miss.	0	0	0	0	0
29	Ark.	0	0	0	0	0
30	La.	0	0	0	0	0
31	Okla.	0	0	0	0	13
32	Tex.	0	0	0	12,639	296
33	Tex.	0	0	0	0	0
34	Tex.	0	0	0	0	0
35	Mont.	2,718	210	122	0	0
36	Mont.	1,083	58	0	1,640	0
37	Wyo.	390	0	0	0	0
38	Col.	3,967	0	0	0	0
39	Ariz.	21	29	0	0	0
40	Idaho	0	1,755	0	0	0
41	Wash.	0	0	0	0	0
42	Cal.	0	0	0	0	0

Regional Price Differentials

A very useful type of information that can be derived from spatial studies is related to regional prices of the products. Although absolute equilibrium prices could not be determined, regional price differentials were determined for each grain and flour at the various origin and destination points. The procedure involved in deriving this information is discussed below.

Regional price differentials for each grain and flour were determined by finding the dual variables associated with the optimal solution. Once a solution to a transhipment problem is found, a set of auxiliary variables, the U_i associated with each of the m rows and the V_j associated with each of the n columns of the transportation cost matrix (Figure 6), may be defined. These are the dual variables of linear programming theory. Their values are chosen so that

$$U_i + V_j = C_{ij} \qquad (20)$$

for those combinations of i and j which correspond to elements ($X_{ij} > 0$) of the basis. Since there are m + n - 1 elements in a basis and m + n dual variables, there is one more unknown than equations, and the value of one of the variables is arbitrary.

The U_i's represent the relative value of the commodity at the origins and the V_j's represent the relative value of the commodity at the destinations. Since one of the variables is arbitrary, absolute equilibrium prices are not determined. Price differentials determined in this manner are based on the assumption that the value of a commodity at a particular destination should differ from its value at the origin(s) supplying that destination by the cost of transfering a unit between the two localities. The difference in price between an origin and destination in which shipments do not take place must be equal to or less than the relevant shipping charges. This implies the following relationship:

$$U_i + V_j - C_{ij} \leq 0 . \tag{21}$$

If this relationship does not hold for all nonbasic elements, an optimum solution has not been found, and total cost can be reduced by introducing elements for which the relationship does not hold into the basis.

The equilibrium regional price differentials derived from Model I for grain origins are presented in Table XXIX. These differentials show the locational advantage of various origins in supplying grain based on marketing costs but excluding production costs. For example, the price differentials for hard wheat in eastern Texas (region (34) and Oklahoma (region 31) are 29.2 and 23.2, respectively. Therefore, a locational advantage of 6.0 cents per bushel accrued to eastern Texas over Oklahoma because of lower transportation rates to the Gulf ports. As compared with southern Kansas, Oklahoma had a locational advantage of 5.1 cents per bushel.

The estimated regional price differentials for grain and flour at destinations are presented in Table XXX. These differentials differ from the differential at origins by the marketing cost involved in moving the grains from origins to destinations. The regional price differentials for wheat are prices at flour mills and reflect the relative disadvantage of mills in various regions in procuring wheat supplies. For example, the hard wheat differentials for Oklahoma (region 31) and southern Kansas (region 19) are 37.5 and 28.9,

TABLE XXIX

ESTIMATED REGIONAL DOMESTIC PRICE DIFFERENTIALS AT GRAIN ORIGINS BY TYPE OF GRAIN, MODEL I

Supply Region		Hard Wheat	Soft Wheat	Durum Wheat	Feed Grain	Soy-beans
		Cents Per Bushel				
1	N.E.	a	a	a	59.4	a
2	N.Y.	51.6	20.5	a	51.1	16.5
3	Pa.	49.2	18.1	a	49.3	11.6
4	Ohio	51.9	18.1	a	40.0	5.7
5	Ind.	46.6	18.1	a	36.4	5.8
6	Ill.	41.4	31.0	a	34.0	7.5
7	Ill.	41.4	34.3	a	33.6	11.7
8	Mich.	47.6	18.9	a	38.0	12.3
9	Wisc.	33.3	18.1	a	32.5	13.1
10	Minn.	30.6	30.6	18.1	17.0	5.7
11	Minn.	30.1	a	33.8	31.5	5.7
12	Iowa	27.3	a	a	22.3	5.7
13	Iowa	31.3	a	a	21.3	5.7
14	Mo.	27.8	32.2	a	30.3	5.7
15	N.D.	12.4	a	12.4	11.4	0.0
16	S.D.	18.1	a	18.6	17.0	5.7
17	Neb.	18.7	a	a	17.0	5.7
18	Kan.	18.1	a	a	17.0	5.7
19	Kan.	18.1	a	a	17.0	9.6
20	Va.	52.8	26.9	a	52.6	16.4
21	N.C.	a	30.1	a	56.2	11.3
22	S.C.	a	30.7	a	40.4	6.5
23	Ga.	a	32.2	a	45.4	10.6
24	Fla.	a	18.8	a	36.4	18.6
25	Ky.	a	34.5	a	30.8	16.2
26	Tenn.	a	32.1	a	25.0	21.2
27	Ala.	a	28.4	a	42.8	22.2
28	Miss.	a	38.7	a	41.0	14.5
29	Ark.	33.9	39.1	a	42.5	16.2
30	La.	36.4	41.6	a	30.7	17.6
31	Okla.	23.2	a	a	19.8	6.8
32	Tex.	23.2	a	a	17.0	5.7
33	Tex.	38.4	a	a	31.8	25.0
34	Tex.	29.2	a	a	26.6	10.4
35	Mont.	0.0	0.0	0.0	0.0	a
36	Mont.	13.8	13.8	14.8	12.7	a
37	Wyo.	18.1	23.1	a	27.0	a
38	Col.	18.1	a	a	29.0	a
39	Ariz.	18.1	18.1	a	23.6	a
40	Idaho	23.1	18.1	a	30.1	a
41	Wash.	41.0	34.3	a	35.7	a
42	Cal.	55.1	48.4	34.2	55.2	a

[a]Price differential was not computed.

TABLE XXX

ESTIMATED REGIONAL PRICE DIFFERENTIALS AT GRAIN DESTINATIONS BY TYPE OF GRAIN AND FLOUR (WHEAT EQUIVALENT), MODEL I

Demand Region		Hard Wheat	Hard Flour	Soft Wheat	Soft Flour	Durum Wheat	Feed Grain	Soy- beans
					Cents Per Bushel			
1	N.E.	a	120.4	a	107.7	a	71.6	a
2	N.Y.	62.9	110.8	38.4	86.2	61.4	67.4	a
3	Pa.	65.3	110.7	38.5	83.9	a	65.4	22.2
4	Ohio	63.7	94.8	30.0	61.1	a	50.7	14.1
5	Ind.	56.8	87.2	28.6	59.1	a	45.7	13.2
6	Ill.	48.4	83.6	36.6	71.8	a	46.2	20.3
7	Ill.	52.5	78.8	45.5	75.2	a	44.2	20.6
8	Mich.	58.7	92.1	30.0	63.5	a	48.7	a
9	Wisc.	44.4	83.6	29.3	74.1	38.8	43.2	a
10	Minn.	44.9	76.0	51.3	82.4	38.7	31.5	20.7
11	Minn.	43.0	71.7	49.6	78.2	37.0	31.5	14.1
12	Iowa	a	82.4	a	80.1	a	31.3	12.9
13	Iowa	40.8	67.8	47.5	74.6	a	30.3	13.5
14	Mo.	39.9	66.9	44.4	71.4	a	37.6	15.8
15	N.D.	28.6	58.1	54.8	84.3	28.6	28.4	a
16	S.D.	32.4	83.8	34.5	85.9	32.9	30.8	a
17	Neb.	29.5	66.3	51.6	88.4	a	27.4	14.4
18	Kan.	32.8	61.8	49.7	78.7	a	31.7	17.7
19	Kan.	28.9	62.9	52.0	86.0	a	28.2	18.3
20	Va.	63.6	110.3	38.2	85.0	a	63.4	24.8
21	N.C.	63.6	112.0	41.4	89.8	a	62.8	19.8
22	S.C.	61.4	119.5	43.3	101.5	a	52.6	13.2
23	Ga.	58.2	110.8	47.4	100.0	a	58.1	19.0
24	Fla.	53.7	119.3	38.6	104.3	a	52.7	a
25	Ky.	41.8	92.4	34.7	73.1	a	43.6	19.8
26	Tenn.	47.0	88.4	43.4	84.8	a	35.8	28.5
27	Ala.	45.3	104.2	38.4	97.4	a	52.2	30.3
28	Miss.	47.2	102.4	51.4	106.8	a	53.2	24.2
29	Ark.	a	79.8	a	87.4	a	54.7	27.2
30	La.	a	90.3	a	101.0	a	46.9	a
31	Okla.	37.5	65.4	65.6	93.5	a	35.4	20.2
32	Tex.	37.1	83.6	55.8	102.3	a	31.3	a
33	Tex.	52.4	90.3	63.1	101.0	a	49.3	a
34	Tex.	43.1	73.3	65.2	95.4	a	40.9	a
35	Mont.	a	82.8	a	82.8	10.9	17.1	a
36	Mont.	24.8	55.4	24.7	55.4	25.3	20.8	a
37	Wyo.	30.8	76.5	33.7	79.4	a	29.5	a
38	Col.	30.3	60.9	63.8	94.4	a	40.7	a
39	Ariz.	31.8	108.3	31.7	112.9	a	38.6	a
40	Utah	38.0	86.9	33.0	81.9	a	43.3	a
41	Wash.	64.7	94.9	58.0	88.2	64.7	55.6	a
42	Cal.	68.7	111.8	61.9	105.1	a	67.4	a

TABLE XXX (Continued)

Demand Region		Hard Wheat	Hard Flour	Soft Wheat	Soft Flour	Durum Wheat	Feed Grain	Soy-beans
					Cents Per Bushel			
43	Sup.	36.0	76.2	a	a	36.0	35.1	23.7
44	Chic.	43.3	96.2	28.1	71.8	a	44.3	23.3
45	Tol.	a	a	29.0	71.2	a	47.5	25.9
46	Alb.	68.8	a	42.5	a	73.8	59.4	a
47	Balt.	68.8	104.0	37.7	79.7	73.8	59.4	30.7
48	Norf.	68.8	a	42.5	a	73.8	59.4	27.3
49	N.Ch.	61.1	125.3	46.0	97.2	a	56.4	18.0
50	N.O.	52.6	88.3	57.8	88.7	49.9	46.9	34.9
51	Hous.	52.6	88.3	a	a	65.8	47.4	34.9
52	L.B.	60.4	a	55.4	a	a	53.6	a
53	Stk.	60.4	112.1	55.4	a	a	53.6	a
54	Port.	59.4	94.9	55.4	88.2	59.4	50.3	a
55	Seat.	58.8	109.1	52.1	102.4	a	50.3	a

[a]Price differential was not computed.

respectively. This means that a miller at Wichita would have to pay 8.6 cents per bushel less for hard wheat than a miller at Oklahoma City. Thus, the mill at Oklahoma City would have to overcome this disadvantage in order to be competitive with the Kansas mill in various flour markets. The disadvantage was reflected in the fact Oklahoma had unused milling capacity in this analysis (Table XXVII).

The price differentials at port destinations reflect the advantage of various port regions in terms of domestic marketing costs. For example, ports on the Gulf (regions 50 and 51) have an advantage over the major ports on the Atlantic (regions 46-48) of 16.2 cents per bushel in exporting hard wheat. Duluth-Superior had a locational advantage of 16.6 and 32.8 cents per bushel over the Gulf and Atlantic ports, respectively. To determine the absolute locational advantage of the various ports, ocean freight charges would have to be considered also, and these were not included in the model.

A discussion of the total marketing cost associated with Model I will be deferred until the solutions of Models II and III have been presented. This will facilitate a comparison of the marketing costs incurred under each situation.

Model II

Model II was designed to provide guides for the flour milling industry in making locational adjustments consistent with the existing transportation rate structure. The key element affecting the location of flour milling is the relationship between the cost of transporting wheat and the cost of transporting flour. This relationship has undergone significant changes in recent years. The factors involved and the direction of these changes were discussed in Chapter I, and the effects of such changes were elaborated in Chapter II.

The conditions of Model II were identical to those of Model I except for the assumption concerning milling capacity constraints. In Model I flour milling capacity was assumed to be the actual 1967 capacity for 254 days of operation. In Model II all capacity restrictions were relaxed, and the capacity of each region was permitted to seek an optimum or equilibrium level. An analysis of this type can be very useful in investigating the extent to which the locational pattern of the flour milling industry was suboptimal in 1966-67. The direction of desirable locational changes also can be determined along with the savings that would result if locational changes are made. The results are dependent upon the supply and demand condition of 1966-67 and the cost relationships that were incorporated into the model. These conditions are continuously changing, and each change modifies the optimum organization of the industry. Therefore, the adjustments outlined here are not predictions of the future locational orientation of the flour milling industry.

This analysis is similar in many respects to Weber's model that was presented in Chapter II. The similarity results from the fact that raw material sources and market requirements are fixed and the location of processing is a variable. The relationship between transportation rates for raw materials (wheat) and processed products (flour) is the critical factor in this analysis. The effects on mill location of having differential rates for domestic and export shipments of wheat will also become more apparent in this analysis.

The results presented for Model II are restricted to hard and soft wheat and the flour milled from each. The optimum flow patterns for durum wheat, feed grain, and soybeans were not affected by a relaxation of milling capacity constraints and were the same as those determined for Model I. The net changes from Model I in the volumes shipped and milled will be emphasized rather than the absolute volumes.

The model did not consider milling activities in regions that did not have flour mills in Model I. Hence, flour milling was not permitted to shift to New England, Arkansas, Louisiana, northern Iowa, and eastern Montana, and the location of milling was restricted to that extent.

Optimum Geographical Flows

Hard-Wheat

The changes in optimum geographical flows of hard-wheat from supply regions to flour mills and to export points that resulted from relaxing milling capacity restrictions are presented in Table XXXI. For example, in Model II there was no change in the volume of hard-wheat shipped from New York to Baltimore, and shipments from Pennsylvania to Baltimore increased by 5.6 million bushels while shipments to local mills were reduced by this amount. In general, the most significant change in the domestic market under this model was a substantial increase in shipments from the West North Central states. Shipments from Minnesota to Michigan, Florida and Tennessee increased by about 9.4, 9.5 and 2.0 million bushels, respectively. Sizable increases also occurred in shipments from Missouri to Kentucky, Alabama and Mississippi. Nebraska shipped about 18 million bushels to Ohio, and shipments from northern Kansas to New York, northern Illinois, and

TABLE XXXI

NET CHANGE FROM MODEL I IN THE VOLUME OF HARD WHEAT SHIPPED FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL II

Supply Region		Demand Region		Change in Quantity	Supply Region		Demand Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
2	N.Y.	47	Balt.	0	17	Neb.	48	Norf.	0
3	Pa.	3	Pa.	-560			50	N.O.	-2,610
		47	Balt.	560	18	Kan.	2	N.Y.	991
4	Ohio	4	Ohio	0			6	Ill.	707
5	Ind.	4	Ohio	0			18	Kan.	-2,508
6	Ill.	6	Ill.	19			20	Va.	-205
		47	Balt.	-19			21	N.C.	-7
7	Ill.	7	Ill.	-254			22	S.C.	449
		46	Alb.	254	19	Kan.	19	Kan.	1,841
8	Mich.	8	Mich.	0			33	Tex.	0
9	Wisc.	4	Ohio	-1,210			50	N.O.	2,610
		5	Ind.	408			51	Hous.	-1,466
		9	Wisc.	802	20	Va.	48	Norf.	0
		44	Chic.	0	29	Ark.	50	N.O.	0
10	Minn.	2	N.Y.	-945	30	La.	50	N.O.	0
		8	Mich.	945	31	Okla.	31	Okla.	-633
11	Minn.	11	Minn.	-175			51	Hous.	633
		24	Fla.	952	32	Tex.	32	Tex.	333
		26	Tenn.	201			39	Ariz.	237
		49	N.Ch.	0			51	Hous.	-570
12	Iowa	11	Minn.	92	33	Tex.	33	Tex.	0
		13	Iowa	-92	34	Tex.	34	Tex.	-1,403
13	Iowa	13	Iowa	0			51	Hous.	1,403
14	Mo.	14	Mo.	-1,167	35	Mont.	41	Wash.	-51
		23	Ga.	-53			54	Port.	11
		25	Ky.	359	36	Mont.	36	Mont.	0
		27	Ala.	410			54	Port.	16
		28	Miss.	451	37	Wyo.	37	Wyo.	0
15	N.D.	10	Minn.	75			52	L.B.	34
		15	N.D.	-189	38	Col.	38	Col.	-258
		43	Sup.	0			53	Stk.	17
		54	Port.	-27	39	Ariz.	39	Ariz.	21
16	S.D.	11	Minn.	978[a]	40	Idaho	40	Utah	1,017
		11	Minn.	-3,013			42	Cal.	-966
		16	S.D.	2			52	L.B.	-34
17	Neb.	4	Ohio	1,827			53	Stk.	-17
		17	Neb.	1,578	41	Wash.	41	Wash.	0
		46	Alb.	-254			55	Seat.	0
		47	Balt.	-541	42	Cal.	42	Cal.	0

[a]This quantity was transhipped to Minnesota for subsequent shipment.

South Carolina increased by several million bushels. The most significant change in the West involved an increase in Utah mill receipts of about 10 million bushels from local sources and a corresponding reduction in shipments from this region to California.

In the export market, there was an increase in shipments from Oklahoma and east Texas (region 34) with a corresponding reduction in shipments to local mills (Table XXXI). These increases replaced quantities previously drawn from west Texas and southern Kansas. Shipments to New Orleans from Nebraska were replaced with shipments from southern Kansas. Shipments from Nebraska to Atlantic ports decreased and these needs were supplied from Pennsylvania and southern Illinois.

Hard-Wheat Flour

The shifts in the optimum flow pattern for hard wheat had associated adjustments in the optimum flows of hard-wheat flour. The changes in the optimum geographical flow of hard-wheat flour from flour mills to demand points are presented in Table XXXII. The increased outflow of wheat from West North Central states noted above reduced the flour shipments from these states considerably. A majority of the regions east of the Mississippi River became self-sufficient in hard-wheat flour production, and shipments of flour from Minnesota, Missouri and Kansas to these regions were drastically reduced. In the West, Utah millers supplied a major portion of California's hard-wheat flour needs.

Some significant shifts also occurred in the export market. Shipments from southern Kansas to New Orleans and Houston increased by 3.7 and 14.0 bushel equivalents, respectively. As a result, northern Kansas and east Texas lost their share of the export markets. The

TABLE XXXII

NET CHANGE FROM MODEL I IN THE VOLUME OF HARD-WHEAT FLOUR (WHEAT EQUIVALENTS) SHIPPED FROM MILLING REGIONS TO DEMAND REGIONS, MODEL II

Milling Region	Demand Region	Change in Quantity	Milling Region	Demand Region	Change in Quantity
		10,000 Bu.			10,000 Bu.
2 N.Y.	1 N.E.	0	18 Kan.	50 N.O.	-366
	2 N.Y.	46	19 Kan.	2 N.Y.	-46
3 Pa.	3 Pa.	-560		19 Kan.	0
4 Ohio	4 Ohio	460		20 Va.	205
5 Ind.	5 Ind.	565		23 Ga.	-450
6 Ill.	6 Ill.	760		50 N.O.	366
	44 Chic.	-34		51 Hous.	1,403
7 Ill.	3 Pa.	-343	20 Va.	20 Va.	-205
	7 Ill.	439	21 N.C.	21 N.C.	32
8 Mich.	3 Pa.	-58		49 N.Ch.	-39
	8 Mich.	1,003	22 S.C.	22 S.C.	390
9 Wisc.	9 Wisc.	768		49 N.Ch.	39
	44 Chic.	34	23 Ga.	23 Ga.	-53
10 Minn.	10 Minn.	75	24 Fla.	24 Fla.	952
11 Minn.	5 Ind.	-565	25 Ky.	23 Ga.	9
	6 Ill.	-760		25 Ky.	350
	8 Mich.	-1,003	26 Tenn.	23 Ga.	611
	9 Wisc.	-768		26 Tenn.	0
	11 Minn.	0	27 Ala.	27 Ala.	410
13 Iowa	12 Iowa	-92	28 Miss.	28 Miss.	451
	13 Iowa	0	31 Okla.	23 Ga.	-117
14 Mo.	4 Ohio	-460		28 Miss.	-183
	7 Ill.	-439		31 Okla.	0
	14 Mo.	0		32 Tex.	-333
	28 Miss.	-268	32 Tex.	32 Tex.	333
15 N.D.	3 Pa.	-140	33 Tex.	33 Tex.	0
	10 Minn.	-75	34 Tex.	34 Tex.	0
	15 N.D.	0		51 Hous.	-1,403
	16 S.D.	-2	36 Mont.	35 Mont.	0
	43 Sup.	0		36 Mont.	0
16 S.D.	16 S.D.	2	37 Wyo.	37 Wyo.	0
17 Neb.	3 Pa.	1,468	38 Col.	38 Col.	0
	12 Iowa	92		39 Ariz.	-258
	17 Neb.	0	39 Ariz.	39 Ariz.	258
	47 Balt.	0	40 Utah	40 Utah	0
18 Kan.	3 Pa.	-385		42 Cal.	1,017
	18 Kan.	0		53 Stk.	0
	21 N.C.	-32	41 Wash.	41 Wash.	0
	22 S.C.	-410		42 Cal.	-51
	24 Fla.	-952		54 Port.	0
	29 Ark.	-363		55 Seat.	0
	30 La.	0	42 Cal.	42 Cal.	-966

reduction of flour shipments from east Texas to Houston and the corresponding increase in shipments from southern Kansas illustrates that the level of export transportation rates for wheat has important implications for the competitive position of flour mills. In the past, mills in Oklahoma and Texas have supplied a sizable proportion of flour needs at Gulf ports. However, export rates on flour from these regions have not been reduced in proportion to reductions that have occurred in wheat rates, and this has destroyed any locational advantage that these mills may have enjoyed in the past.

Soft Wheat

Compared with hard wheat, changes in the level of shipments were smaller and fewer in number in the case of soft wheat (Table XXXIII). The most notable changes in the domestic market were reductions in mill receipts in Ohio and Indiana from local sources of about 10 and 6 million bushels, respectively. Illinois increased shipments to mill points in the South as well as to local mills. Outside the East North Central region, changes in the domestic flows were much less pronounced; however, mills in several regions had significant increases in the volume procured from nearby supply points.

The most significant increase in shipments for export was an increase of 10 million bushels in shipments from Indiana to New Orleans. This increase was offset by decreases in shipments from Illinois, Mississippi, and Louisiana. Shipments from New York to Baltimore were reduced, and flows from Pennsylvania and Ohio were increased accordingly. Requirements at Stockton and Portland were drawn from adjacent regions in this model and flows from Idaho to these ports were reduced.

TABLE XXXIII

NET CHANGE FROM MODEL I IN THE VOLUME OF SOFT WHEAT SHIPPED FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL II

Supply Region	Demand Region	Change in Quantity	Supply Region	Demand Region	Change in Quantity
		10,000 Bu.			10,000 Bu.
2 N.Y.	2 N.Y.	323	14 Mo.	33 Tex.	252
	47 Balt.	-323	20 Va.	20 Va.	-111
3 Pa.	3 Pa.	0		21 N.C.	111
	47 Balt.	251	21 N.C.	21 N.C.	-272
4 Ohio	4 Ohio	-1,012		22 S.C.	272
	46 Alb.	0		49 N.Ch.	0
	47 Balt.	72	22 S.C.	22 S.C.	0
	48 Norf.	0		23 Ga.	163
5 Ind.	5 Ind.	-618	23 Ga.	23 Ga.	175
	10 Minn.	0	24 Fla.	24 Fla.	0
	13 Iowa	0	25 Ky.	50 N.O.	0
	17 Neb.	0	26 Tenn.	26 Tenn.	0
	18 Kan.	-40	27 Ala.	27 Ala.	0
	19 Kan.	0	28 Miss.	28 Miss.	288
	50 N.O.	1,001		50 N.O.	-288
6 Ill.	24 Fla.	528	29 Ark.	50 N.O.	0
	26 Tenn.	0	30 La.	33 Tex.	81
	27 Ala.	68		50 N.O.	-81
	28 Miss.	-24	35 Mont.	16 S.D.	0
	31 Okla.	-164		37 Wyo.	40
	50 N.O.	-408	36 Mont.	36 Mont.	-16
7 Ill.	7 Ill.	224	37 Wyo.	38 Col.	0
	50 N.O.	-224	39 Ariz.	39 Ariz.	29
8 Mich.	6 Ill.	127	40 Idaho	40 Utah	222
	8 Mich.	-127		52 L.B.	0
	45 Tol.	0		53 Stk.	-12
9 Wisc.	9 Wisc.	306		54 Port.	-82
	44 Chic.	0	41 Wash.	41 Wash.	-223
10 Minn.	10 Minn.	0		54 Port.	82
	11 Minn.	0		55 Seat.	0
	15 N.D.	0	42 Cal.	42 Cal.	-12
14 Mo.	14 Mo.	-430		53 Stk.	12
	27 Ala.	178			

Soft-Wheat Flour

The changes that occurred in soft flour shipments are presented in Table XXXIV. Eight regions experienced a reduction in the total volume shipped to out-of-state markets (regions 4, 5, 6, 8, 14, 18, 36, and 41). The most significant total reduction was present in Ohio shipments where out-of-state shipments were reduced by 10 million bushel equivalents of soft flour. Shipments to ports were unchanged except for Wisconsin replacing Indiana in the Chicago market.

Optimum Organization of the Milling Industry

The changes in the level of regional milling activities and the required changes in capacity that were associated with the above changes in wheat and flour flows are presented in Table XXXV. The information should be interpreted as the adjustments in the organization of the milling industry that would have resulted in a lower total cost to the industry in satisfying the 1967 regional flour requirements given the regional distribution of wheat supplies. These results are dependent upon the basic data employed and are very sensitive to any inaccuracies in data estimation as well as changes in transportation rates that occur over time. Hence, these results are not a prediction of what locational shifts will occur in the milling industry but describe those adjustments that would have resulted in a lower marketing bill for the wheat-flour economy during 1966-67.

The most significant interregional shifts in flour milling involved hard-wheat milling. Fifteen of the 37 regions had a decline in the volume of hard wheat milled. The most serious adjustments occurred in southern Minnesota, Missouri, northern Kansas, and east

TABLE XXXIV

NET CHANGE FROM MODEL I IN THE VOLUME OF SOFT-WHEAT FLOUR (WHEAT EQUIVALENTS) SHIPPED FROM MILLING REGIONS TO DEMAND REGIONS, MODEL II

Milling Region	Demand Region	Change in Quantity	Milling Region	Demand Region	Change in Quantity
		10,000 Bu.			10,000 Bu.
2 N.Y.	1 N.E.	0	14 Mo.	31 Okla.	164
	2 N.Y.	323		32 Tex.	0
3 Pa.	3 Pa.	0		33 Tex.	-333
4 Ohio	2 N.Y.	-323		34 Tex.	0
	4 Ohio	0	15 N.D.	15 N.D.	0
	20 Va.	111	16 S.D.	16 S.D.	0
	22 S.C.	-109	17 Neb.	17 Neb.	0
	23 Ga.	-163	18 Kan.	18 Kan.	0
	24 Fla.	-528		38 Col.	-40
	49 N.Ch.	0	19 Kan.	19 Kan.	0
5 Ind.	5 Ind.	0	20 Va.	20 Va.	-111
	6 Ill.	-354	21 N.C.	21 N.C.	-161
	7 Ill.	0	22 S.C.	22 S.C.	109
	25 Ky.	0	23 Ga.	23 Ga.	163
	27 Ala.	-246	24 Fla.	24 Fla.	528
	44 Chic.	-18	26 Tenn.	26 Tenn.	0
	47 Balt.	0	27 Ala.	27 Ala.	246
	50 N.O.	0	28 Miss.	28 Miss.	264
6 Ill.	6 Ill.	354	31 Okla.	31 Okla.	-164
	14 Mo.	37	33 Tex.	33 Tex.	333
	28 Miss.	-264	36 Mont.	35 Mont.	-16
7 Ill.	29 Ark.	224		36 Mont.	0
8 Mich.	8 Mich.	0	37 Wyo.	37 Wyo.	0
	9 Wisc.	-288		38 Col.	40
	12 Iowa	0	38 Col.	38 Col.	0
	21 N.C.	161	39 Ariz.	39 Ariz.	29
	45 Tol.	0	40 Utah	35 Mont.	16
9 Wisc.	9 Wisc.	288		39 Ariz.	-29
	44 Chic.	18		40 Utah	0
10 Minn.	10 Minn.	0		42 Cal.	235
11 Minn.	11 Minn.	0	41 Wash.	41 Wash.	0
13 Iowa	13 Iowa	0		42 Cal.	-223
14 Mo.	14 Mo.	-37		54 Port.	0
	29 Ark.	-224		55 Seat.	0
	30 La.	0	42 Cal.	42 Cal.	-12

TABLE XXXV

NET CHANGE FROM MODEL I IN REGIONAL VOLUMES OF WHEAT MILLED BY TYPE AND THE CHANGE IN REGIONAL CAPACITY REQUIREMENTS, MODEL II

Milling Region		Change in Volume Milled		Change in Capacity
		Hard Wheat	Soft Wheat	
		10,000 Bu.		
2	N.Y.	46	323	369
3	Pa.	-560	0	-560
4	Ohio	460	-1,012	-552
5	Ind.	565	-618	-53
6	Ill.	726	127	853
7	Ill.	-254	224	-30
8	Mich.	945	-127	818
9	Wisc.	802	306	1,108
10	Minn.	75	0	75
11	Minn.	-3,096	0	-3,096
13	Iowa	-92	0	-674[a]
14	Mo.	-1,167	-430	-2,471[a]
15	N.D.	-217	0	-217
16	S.D.	2	0	2
17	Neb.	1,578	0	1,578
18	Kan.	-2,508	-20	-2,508
19	Kan.	1,841	0	1,841
20	Va.	-205	-111	-316
21	N.C.	-7	-161	-168
22	S.C.	449	109	558
23	Ga.	-53	163	110
24	Fla.	952	528	1,480
25	Ky.	359	0	359
26	Tenn.	201	0	201
27	Ala.	410	246	410
28	Miss.	451	264	715
31	Okla.	-633	-164	-1,279[a]
32	Tex.	333	0	333
33	Tex.	0	333	333
34	Tex.	-1,403	0	-1,403
36	Mont.	0	-16	-440[a]
37	Wyo.	0	40	40
38	Col.	-258	0	-371[a]
39	Ariz.	258	29	287
40	Utah	1,017	222	1,239
41	Wash.	-51	-223	-694[a]
42	Cal.	-966	-12	-978

[a]These figures include excess capacity present in Model I.

Texas where the volumes milled declined by more than 10 million bushels. These and other declines were offset by expansion in hard wheat milling activities in 12 of the 17 milling regions east of the Mississippi River. Four of the regions located along the Atlantic coast (Pennsylvania, Virginia, North Carolina and Georgia) milled a smaller volume of hard wheat. Southern Illinois also milled less hard wheat, but the volume milled in northern Illinois increased by a greater amount. The most significant adjustment in hard-wheat milling in the West was a sizable increase for Utah and a decline in California.

It is not likely that Nebraska and southern Kansas will gain in hard-wheat milling while northern Kansas declines. Northern Kansas had a slight disadvantage in the markets served by the other two regions, and the relative advantage of the three regions could be changed by the selection of different regional supply points. For example, if a wheat origin in northern Kansas closer to the assumed milling point had been chosen, the assembly cost to these mills would have been lower. Consequently, the competitive position of mills in this region would have been improved relative to those of Nebraska and southern Kansas.

The results should also be interpreted in light of the transportation rates used. Point-to-point rail rates were employed, and the competitive position of mills located in southern Minnesota and Missouri would be improved considerably in a model that incorporated transit rates for flour shipment from these mills located between the major wheat production regions and flour markets. Such a rate system certainly would improve the competitive position of these mills in the flour markets of the East North Central region.

The information does suggest that hard-wheat milling activities are likely to increase in the Southeast in the future. These regions have favorable transportation rates via barge-hopper car combination movements of wheat into the area. Virginia and Georgia did not mill any hard wheat in this model. However, the disadvantages of mills in these regions were small and resulted from the much higher milling cost estimates for those states. If milling cost had been reduced to a level comparable with other regions, these states would have been self-sufficient in hard-wheat flour production, and wheat shipments from Kansas would have replaced flour shipments from Kansas, Kentucky and Tennessee.

Shifts in the location of soft-wheat milling activities were much smaller than those related to hard-wheat milling. The most notable changes were substantial decreases in Ohio and Indiana offset by increases in New York, Illinois, and several of the Southeastern states. South Texas had a sizable increase in volume, and there was a 2.2 million bushel shift from Washington to Utah. Thirteen states had no change in the volume of soft wheat milled, and five others had a change in volume of less than one million bushels.

The important question that arises in connection with any discussion of industrial location is how much can marketing costs be reduced if locational adjustments are made? Consideration of this aspect will be delayed until the results of Model III have been presented.

Model III

The geographical flows presented for Model I were the distribution patterns which minimized the cost of satisfying the estimated regional requirements for grain and flour from the available grain supplies. In reality, the interregional movement of grain is a continuous process, and the supplies in the various consumption regions are never completely exhausted as was possible in Model I. Thus, Model III is designed to account for "pipeline" stocks or minimum working inventories that are maintained in all consumption regions to insure a smooth operation of the marketing system.

The conditions of Model III are identical to those of Model I except for some additional assumptions concerning minimum inventory requirements at locations demanding whole grain. All flour milling regions, durum milling regions and domestic feed grain consumption regions were required to have an ending inventory of grain equivalent to 15 percent of annual requirements, and export regions were required to have ending inventories of feed grain and the three types of wheat equivalent to 5 percent of the volume handled during 1966-67. The required wheat inventories in flour milling regions were determined by taking 15 percent of the regional volumes of hard and soft wheat milled in Model I. Minimum regional inventory levels were not specified for soybeans, since the flow of soybeans is only of secondary interest in this study and their flow is independent of the other grains in an annual model. Soybeans were included in this model, but their flows were identical to those determined in Model I and will not be presented again.

Optimum Geographical Flows

The net changes in the optimum flows will be emphasized in this section, and comparisons will be with Model I results. The geographical flows determined with Model III minimized the cost of supplying the estimated regional demands for grain and flour plus inventory requirements at destinations for grain from the available grain supplies.

Hard Wheat

The incorporation of minimum working inventory requirements at flour mills and ports in effect introduced a new source of competition for the available wheat supplies, and this resulted in significant changes in the level of volumes shipped from supply points to milling and export regions (Table XXXVI). In general, there were significant increases in the shipments from regions having stocks in Model I (regions 15, 16, 18, 19, 37, 38, and 39) while shipments from other regions shifted among markets. Free stocks increased in Montana as out-shipments decreased, and the level of only 10 shipping activities were unaffected by the inventory requirements. These unaffected shipments are denoted by zeros in Table XXXVI. The most significant change in the domestic market was in the flows to mills in northern Illinois. The shipments from local sources decreased by 8 million bushels and shipments from Kansas to these mills increased by 11.7 million bushels.

Many of the alterations in flows from supply points involved an increase (decrease) in shipments to domestic destinations and a corresponding decrease (increase) in shipments to export regions. Such changes are apparent in the flows from Illinois. The most significant changes in the export market were found in the North Plains. Shipments from North Dakota to Portland increased by about 25 million bushels replacing shipments previously originating in Montana. Larger shipments from southern Kansas to Gulf ports were required to satisfy

TABLE XXXVI

NET CHANGE FROM MODEL I IN THE VOLUME OF HARD WHEAT SHIPPED FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL III

Supply Region		Demand Region		Change in Quantity	Supply Region		Demand Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
2	N.Y.	47	Balt.	0	18	Kan.	2	N.Y.	495
3	Pa.	3	Pa.	5			6	Ill.	1,172
		47	Balt.	-5			18	Kan.	513
4	Ohio	4	Ohio	0			20	Va.	481
5	Ind.	4	Ohio	0			21	N.C.	81
6	Ill.	6	Ill.	-802			22	S.C.	235
		47	Balt.	802			23	Ga.	87
7	Ill.	7	Ill.	279	19	Kan.	19	Kan.	683
		46	Alb.	-279			33	Tex.	113
8	Mich.	8	Mich.	0			50	N.O.	414
9	Wisc.	4	Ohio	-2			51	Hous.	1,775
		44	Chic.	3	20	Va.	48	Norf.	0
10	Minn.	2	N.Y.	-152	29	Ark.	50	N.O.	0
		8	Mich.	152	30	La.	50	N.O.	0
11	Minn.	11	Minn.	-175	31	Okla.	31	Okla.	366
		24	Fla.	22			51	Hous.	-366
		26	Tenn.	145	32	Tex.	32	Tex.	10
		49	N.Ch.	8			51	Hous.	-10
12	Iowa	11	Minn.	-77	33	Tex.	33	Tex.	0
		13	Iowa	77	34	Tex.	34	Tex.	359
13	Iowa	13	Iowa	0			51	Hous.	-359
14	Mo.	14	Mo.	-45	35	Mont.	41	Wash.	676
		23	Ga.	-53			54	Port.	-755
		25	Ky.	40	36	Mont.	36	Mont.	19
		27	Ala.	58			54	Port.	-1,436
15	N.D.	9	Wisc.	11	37	Wyo.	37	Wyo.	8
		10	Minn.	589	38	Col.	38	Col.	66
		15	N.D.	55			52	L.B.	36
		43	Sup.	68			53	Stk.	18
		54	Port.	2,481	39	Ariz.	39	Ariz.	21
16	S.D.	11	Minn.	329	40	Idaho	40	Utah	-229
		16	S.D.	19			42	Cal.	280
17	Neb.	17	Neb.	236			52	L.B.	-34
		46	Alb.	319			53	Stk.	-17
		47	Balt.	-616	41	Wash.	41	Wash.	-64
		48	Norf.	66			55	Seat.	64
		50	N.O.	-5	42	Cal.	42	Cal.	0

inventory requirements at these ports and replace some grain that was held in inventory in Oklahoma and Texas rather than moving to Houston.

Hard-Wheat Flour

The minimum inventory requirements resulted in some changes in the type of wheat milled in the various regions, and the optimum flows of hard flour were adjusted accordingly. The net changes in the level of flour shipments from the milling regions to flour demand centers when compared with Model I are presented in Table XXXVII. New York mills, for example, shipped the same volume to New England, but they milled and shipped 3.2 million bushels less to the New York flour demand point. Mills in Pennsylvania and Ohio also shipped less hard flour to local destinations, and shipments of flour from Michigan, Minnesota and Kansas to these markets increased. Minnesota shipments to northern Illinois decreased and Illinois mills gained in that market. Two notable shifts occurred in flows to Southeastern markets. First, Virginia mills milled 4.5 million bushels more for that market and shipments from southern Kansas were reduced. Second, Oklahoma mills gained at the expense of Missouri mills in the Mississippi market. The most notable change in the West involved the California market, and shipments from Utah declined while shipments from Washington and local mills increased to that destination.

Soft Wheat

The changes that occurred in the level of soft wheat shipments from supply regions to milling and export points are shown in Table XXXVIII. To satisfy the inventory requirements, shipments from regions

TABLE XXXVII

NET CHANGE FROM MODEL I IN THE VOLUME OF HARD-WHEAT FLOUR (WHEAT EQUIVALENTS) SHIPPED FROM MILLING REGIONS TO DEMAND REGIONS, MODEL III

Milling Region		Demand Region		Change in Quantity	Milling Region		Demand Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
2	N.Y.	1	N.E.	0	19	Kan.	2	N.Y.	323
		2	N.Y.	-323			19	Kan.	0
3	Pa.	3	Pa.	-79			20	Va.	-450
4	Ohio	4	Ohio	-213			23	Ga.	69
6	Ill.	6	Ill.	250			50	N.O.	58
		44	Chic.	0			51	Hous.	0
7	Ill.	3	Pa.	0	20	Va.	20	Va.	450
		25	Ky.	0	21	N.C.	21	N.C.	-60
8	Mich.	3	Pa.	23			49	N.Ch.	0
		8	Mich.	37	22	S.C.	22	S.C.	52
10	Minn.	10	Minn.	0	23	Ga.	23	Ga.	26
11	Minn.	4	Ohio	287	24	Fla.	24	Fla.	8
		5	Ind.	0	25	Ky.	25	Ky.	0
		6	Ill.	-250	26	Tenn.	23	Ga.	-30
		8	Mich.	-37			26	Tenn.	0
		9	Wisc.	0			27	Ala.	-22
		11	Minn.	0	27	Ala.	27	Ala.	22
13	Iowa	12	Iowa	0	31	Okla.	23	Ga.	-65
		13	Iowa	0			28	Miss.	268
14	Mo.	4	Ohio	-74			31	Okla.	0
		7	Ill.	0			32	Tex.	0
		14	Mo.	0	32	Tex.	32	Tex.	0
		28	Miss.	-268	33	Tex.	33	Tex.	0
15	N.D.	3	Pa.	0	34	Tex.	34	Tex.	0
		10	Minn.	0			51	Hous.	0
		15	N.D.	0	36	Mont.	35	Mont.	0
		16	S.D.	0			36	Mont.	0
		43	Sup.	0	37	Wyo.	37	Wyo.	0
16	S.D.	16	S.D.	0	38	Col.	38	Col.	0
17	Neb.	3	Pa.	0			39	Ariz.	-21
		17	Neb.	0	39	Ariz.	39	Ariz.	21
		47	Balt.	0	40	Utah	40	Utah	0
18	Kan.	3	Pa.	56			42	Cal.	-439
		18	Kan.	0			53	Stk.	0
		21	N.C.	60	41	Wash.	41	Wash.	0
		22	S.C.	-52			42	Cal.	314
		24	Fla.	-8			54	Port.	0
		29	Ark.	0			55	Seat.	0
		30	La.	0	42	Cal.	42	Cal.	125
		50	N.O.	-58					

TABLE XXXVIII

NET CHANGE FROM MODEL I IN THE VOLUME OF SOFT WHEAT SHIPPED FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL III

Supply Region	Demand Region	Change in Quantity	Supply Region	Demand Region	Change in Quantity
		10,000 Bu.			10,000 Bu.
2 N.Y.	2 N.Y.	497	14 Mo.	14 Mo.	0
	47 Balt.	-497	20 Va.	20 Va.	-380
3 Pa.	3 Pa.	217		21 N.C.	93
	47 Balt.	34		48 Norf.	287
4 Ohio	4 Ohio	545	21 N.C.	21 N.C.	23
	46 Alb.	18		22 S.C.	-24
	47 Balt.	519		49 N.Ch.	1
	48 Norf.	-300	22 S.C.	22 S.C.	0
5 Ind.	5 Ind.	249	23 Ga.	23 Ga.	0
	10 Minn.	28	24 Fla.	24 Fla.	0
	11 Minn.	16	25 Ky.	50 N.O.	0
	13 Iowa	19	26 Tenn.	26 Tenn.	0
	14 Mo.	439	27 Ala.	27 Ala.	0
	17 Neb.	16	28 Miss.	50 N.O.	0
	18 Kan.	20	29 Ark.	50 N.O.	0
	19 Kan.	12	30 La.	33 Tex.	15
	50 N.O.	462		50 N.O.	-15
6 Ill.	26 Tenn.	116	35 Mont.	16 S.D.	8
	28 Miss.	4		37 Wyo.	16
	31 Okla.	125	36 Mont.	36 Mont.	8
	50 N.O.	-245	37 Wyo.	38 Col.	0
7 Ill.	50 N.O.	0	39 Ariz.	39 Ariz.	-14
8 Mich.	6 Ill.	-179	40 Idaho	40 Utah	469
	8 Mich.	114		52 L.B.	0
	45 Tol.	65		53 Stk.	1
9 Wisc.	9 Wisc.	1		54 Port.	428
	44 Chic.	5	41 Wash.	41 Wash.	-155
10 Minn.	10 Minn.	-20		54 Port.	37
	11 Minn.	13		55 Seat.	118
	15 N.D.	7	42 Cal.	42 Cal.	0

having stocks in Model I increased significantly. Total shipments from Ohio, Indiana and Idaho increased by 8.3, 12.6, and 9.0 million bushels, respectively. Shipments from New York and Ohio to local mills increased more than required to meet inventory requirements as the volume milled in these regions increased an amount equivalent to the decrease in hard-wheat milling in those regions. Similarly, shipments to local mills and the volume milled in Virginia decreased since the volume of hard wheat milled in that region increased. In the West, domestic shipments from Idaho to Utah increased by 4.7 million bushels, and shipments from Washington to local mills decreased about 1.6 million bushels.

In export market flows, New York, Illinois and Louisiana shipped less to ports while shipments from Ohio, Indiana, Virginia, and Idaho to port destinations increased by over 2 million bushels in each case. Smaller increases were present from other origins. In many of the regions, the total volume shipped was the same, but adjustments were present in the proportion of total shipments moving to domestic and to export destinations.

Soft-Wheat Flour

The geographical flows of soft flour were characterized by much more stability as compared with hard flour. Thirty-eight of the soft flour shipping activities were unchanged from Model I (Table XXXIX). Shipments from New York mills to local destinations increased, replacing shipments previously originating in Ohio. Ohio millers increased their market share in all South Atlantic states except North Carolina. These states in turn procured less soft flour from local mills. Missouri millers gained at the expense of millers in northern

TABLE XXXIX

NET CHANGE FROM MODEL I IN THE VOLUME OF SOFT-WHEAT FLOUR (WHEAT EQUIVALENTS) SHIPPED FROM MILLING REGIONS TO DEMAND REGIONS, MODEL III

Milling Region		Demand Region		Change in Quantity	Milling Region		Demand Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
2	N.Y.	1	N.E.	0	14	Mo.	32	Tex.	0
		2	N.Y.	323			33	Tex.	0
3	Pa.	3	Pa.	0			34	Tex.	0
4	Ohio	2	N.Y.	-323	15	N.D.	15	N.D.	0
		4	Ohio	373	16	S.D.	16	S.D.	0
		20	Va.	450	17	Neb.	17	Neb.	0
		22	S.C.	52	18	Kan.	18	Kan.	0
		23	Ga.	26			38	Col.	2
		24	Fla.	8	19	Kan.	19	Kan.	0
		49	N.Ch.	0	20	Va.	20	Va.	-450
5	Ind.	5	Ind.	0	21	N.C.	21	N.C.	60
		6	Ill.	30	22	S.C.	22	S.C.	-52
		7	Ill.	0	23	Ga.	23	Ga.	-26
		25	Ky.	0	24	Fla.	24	Fla.	-8
		27	Ala.	-30	26	Tenn.	26	Tenn.	0
		44	Chic.	0			27	Ala.	52
		47	Balt.	0	27	Ala.	27	Ala.	-22
		50	N.O.	0	28	Miss.	28	Miss.	0
6	Ill.	6	Ill.	-30	31	Okla.	31	Okla.	100
		28	Miss.	-220	33	Tex.	33	Tex.	0
8	Mich.	8	Mich.	0	36	Mont.	35	Mont.	0
		9	Wisc.	0			36	Mont.	0
		12	Iowa	0	37	Wyo.	37	Wyo.	0
		21	N.C.	-60			38	Col.	0
		45	Tol.	0	38	Col.	38	Col.	-2
9	Wisc.	9	Wisc.	0	39	Ariz.	39	Ariz.	27
10	Minn.	10	Minn.	0	40	Utah	39	Ariz.	21
11	Minn.	11	Minn.	0			40	Utah	0
13	Iowa	13	Iowa	0			42	Cal.	380
14	Mo.	14	Mo.	0			55	Seat.	38
		28	Miss.	220	41	Wash.	41	Wash.	0
		29	Ark.	0			42	Cal.	-223
		30	La.	0			54	Port.	0
		31	Okla.	-100			55	Seat.	-38
					42	Cal.	42	Cal.	-157

Illinois in the Mississippi flour market, and Utah mills had a considerable increase in shipments to California. Corresponding reductions in shipments from Washington and local mills were present. The only change in the export flow involved an increase in shipments from Utah to Seattle and a decrease in shipments to this port from Washington.

Durum Wheat

The durum wheat flow pattern to milling points was essentially the same but somewhat larger shipments were present. Northern Minnesota increased shipments to New York and Wisconsin and shipped less to southern Minnesota, while shipments from southern Minnesota to local mills increased (Table XL). Mills in North Dakota and Washington received larger quantities from the same sources.

Some notable changes were present in the export market flows. The Norfolk market drew a larger proportion of needs from South Dakota, and the Baltimore market drew most of its supplies from North Dakota rather than South Dakota. North Dakota continued to supply the needs at Superior.

Feed Grain

Introducing the requirement that working inventories of feed grain at domestic destinations must be 15 percent of annual procurements from commercial sources had a pronounced effect on the flows from many supply regions. As the available supplies were exhausted in many of the surplus regions, deficit regions were forced to draw part or all of their needs from more distant sources.

TABLE XL

NET CHANGE FROM MODEL I IN THE VOLUME OF DURUM WHEAT SHIPPED FROM SUPPLY REGIONS TO DEMAND REGIONS, MODEL III

Supply Region		Demand Region		Change in Quantity	Supply Region		Demand Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
10	Minn.	2	N.Y.	36	15	N.D.	46	Alb.	7
		9	Wisc.	76			47	Balt.	303
		10	Minn.	0	16	S.D.	16	S.D.	0
		11	Minn.	-71			47	Balt.	-287
11	Minn.	11	Minn.	211			48	Norf.	289
		46	Alb.	-3	35	Mont.	35	Mont.	0
		48	Norf.	-248			41	Wash.	55
		50	N.O.	36			54	Port.	0
		51	Hous.	4	36	Mont.	36	Mont.	0
15	N.D.	15	N.D.	32			41	Wash.	0
		43	Sup.	137	42	Cal.	54	Port.	0

Flows within the deficit Northeast (regions 1, 2 and 3) and Southeast (regions 20-30) were unchanged except for a reduction of 20,000 bushels to local demands in South Carolina (Table XLI). In Model I the deficits in Northeastern states were satisfied entirely by shipments from Ohio, Indiana, and Michigan. In Model III additional shipments of about 45 million bushels originated in northern Illinois and moved to the New York destination. The increase in shipments from Ohio to Pennsylvania brought about a reduction in flows from Ohio to Virginia. As a result, additional quantities were shipped to Virginia from southern Illinois. The two Illinois regions supplied all the additional requirements of the South Atlantic states (regions 20-24), and shipments to Alabama and Mississippi were reduced accordingly. In this model, Alabama's optimum supply sources were Missouri and northern Kansas, and Mississippi increased receipts from Texas. The significant increase in flows from Missouri to Alabama eliminated flows from Missouri to Arkansas and the requirements in Arkansas were satisfied with shipments from Nebraska. Northern Kansas supplied the needs of Kentucky in this model.

Domestic shipments in the West were characterized by much less change and the only major shift in flows involved shipments from Montana to Washington. These shipments originated in western Montana (region 36) in this model.

Flows of feed grain to ports involved some major changes in the volume shipped from various regions. Shipments to New Orleans from northern Illinois and southern Minnesota decreased about 24 and 44 million bushels, respectively (Table XLII). These reductions plus inventory requirements of 5 percent of exports at that port resulted

TABLE XLI

NET CHANGE FROM MODEL I IN THE VOLUME OF FEED GRAIN SHIPPED FROM SUPPLY REGIONS TO DOMESTIC DEMAND REGIONS, MODEL III

Supply Region	Demand Region	Change in Quantity	Supply Region	Demand Region	Change in Quantity
		10,000 Bu.			10,000 Bu.
1 N.E.	1 N.E.	0	17 Neb.	17 Neb.	1,154
2 N.Y.	2 N.Y.	0		29 Ark.	9,822
3 Pa.	3 Pa.	0		38 Col.	512
4 Ohio	3 Pa.	1,662		42 Cal.	3,112
	4 Ohio	375	18 Kan.	14 Mo.	4,914
	20 Va.	-2,037		18 Kan.	287
5 Ind.	1 N.E.	320		25 Ky.	3,435
	2 N.Y.	-3,223		27 Ala.	1,667
	3 Pa.	1,413	19 Kan.	19 Kan.	141
	5 Ind.	1,143		29 Ark.	189
	8 Mich.	347		31 Okla.	551
6 Ill.	2 N.Y.	4,482	20 Va.	20 Va.	0
	23 Ga.	1,425	21 N.C.	21 N.C.	0
	24 Fla.	2,998	22 S.C.	22 S.C.	-2
	27 Ala.	-6,105	23 Ga.	23 Ga.	0
	28 Miss.	-629	24 Fla.	24 Fla.	0
7 Ill.	20 Va.	2,733	25 Ky.	25 Ky.	0
	21 N.C.	2,022	26 Tenn.	26 Tenn.	0
	22 S.C.	444	27 Ala.	27 Ala.	0
	27 Ala.	-5,199	28 Miss.	28 Miss.	0
8 Mich.	3 Pa.	-281	29 Ark.	29 Ark.	0
	8 Mich.	174	30 La.	30 La.	0
9 Wisc.	6 Ill.	587	31 Okla.	29 Ark.	0
	9 Wisc.	908	32 Tex.	32 Tex.	401
11 Minn.	30 La.	395		34 Tex.	3,070
12 Iowa	6 Ill.	-1,645	33 Tex.	33 Tex.	764
	12 Iowa	413	34 Tex.	28 Miss.	1,894
	26 Tenn.	1,232		34 Tex.	-1,894
13 Iowa	6 Ill.	2,726	35 Mont.	35 Mont.	21
	7 Ill.	1,166		36 Mont.	44
	13 Iowa	1,819		37 Wyo.	26
	14 Mo.	-2,933		41 Wash.	-1,156
	24 Fla.	-2,778	36 Mont.	40 Utah	370
14 Mo.	25 Ky.	-2,601		41 Wash.	2,013
	27 Ala.	10,478	37 Wyo.	38 Col.	0
	29 Ark.	-7,892	38 Col.	38 Col.	0
15 N.D.	11 Minn.	-3,995[a]	39 Ariz.	39 Ariz.	203
	11 Minn.	310	40 Idaho	40 Utah	0
	15 N.D.	2	41 Wash.	41 Wash.	0
16 S.D.	16 S.D.	162	42 Cal.	42 Cal.	0

[a]These quantities were transhipped through storage facilities at destination.

TABLE XLII

NET CHANGE FROM MODEL I IN THE VOLUME OF FEED GRAIN SHIPPED FROM SUPPLY REGIONS TO EXPORT DEMAND REGIONS, MODEL III

Supply Region		Export Region		Change in Quantity	Supply Region		Export Region		Change in Quantity
				10,000 Bu.					10,000 Bu.
6	Ill.	46	Alb.	20	17	Neb.	50	N.O.	8,694
		47	Balt.	132	22	S.C.	49	N.Ch.	2
		48	Norf.	101	32	Tex.	51	Hous.	1,724
		50	N.O.	-2,427			52	L.B.	412
8	Mich.	45	Tol.	107			53	Stk.	46
9	Wisc.	44	Chic	-1,495	33	Tex.	51	Hous.	-764
10	Minn.	43	Sup.	328	35	Mont.	54	Port.	773
11	Minn.	50	N.O.	-4,390			55	Seat.	292
14	Mo.	50	N.O.	15	36	Mont.	54	Port.	-696
16	S.D.	44	Chic.	1,778	39	Ariz.	52	L.B.	-203

in shipments of 87 million bushels from Nebraska to New Orleans. The reduction in shipments from Minnesota had associated reductions of volumes transhipped into that region from North Dakota (see Table XLI). Requirements at the Chicago port were drawn from South Dakota rather than Wisconsin in this model. In the West, shipments to Portland from eastern Montana increased while shipments from western Montana decreased.

Requiring working inventories in domestic and port regions significantly reduced "free" or surplus inventories of feed grain in several regions. The inventory position of the North Plains (regions 10, 11, 15, and 16) actually increased by about 14 million bushels since some storage space previously occupied by wheat was released when wheat shipments from these states increased. The free stocks of feed grain in Kansas (Table XXVIII) were completely exhausted, and the free stocks in Nebraska, western Texas, and western Montana were reduced by 233, 57 and 14 million bushels, respectively. A free stock level of 76 million bushels of feed grain in Nebraska was the highest of all regions in this model.

Utilization of Milling Capacity

Although there were some notable changes in the volumes of hard and soft wheat received at mill points and associated shifts in the type of flour shipped from mills of the various regions in Model III, most of the changes in the regional volume of hard wheat milled were offset by changes in the volume of soft wheat milled. Consequently, only six regions had a change in the total volume of wheat milled. The volumes milled in Oklahoma and Washington increased 3.03 and 0.53 million bushels, respectively, and unused milling capacity in these regions was reduced by this amount. The volumes milled in Pennsylvania, Missouri, Colorado and California decreased by 0.79, 2.22, 0.23 and 0.32 million bushels, respectively. The total volume milled in each of the other regions was unchanged from Model I.

Comparative Cost Analysis

The costs associated with each of the models will be broken down into three categories for presentation. They are (1) domestic transportation, (2) transportation to ports and (3) milling. Handling costs associated with the shipping and receiving of grain are included in transportation costs. Storage costs will not be presented since only ending inventories incur storage charges in annual models and this is only a small portion of the actual cost of storage.

The total costs associated with each model for the three categories are presented by product in Table XLIII and illustrated in Figure 19. Model I resulted in a total cost of $1,377 million with domestic transportation, export transportation and milling accounting for $797, $425 and $155 million, respectively. Comparable total cost figures for Models II and III are $1,365 and $1,550 million, respectively.

The costs associated with the marketing of durum wheat, feed grain and soybeans were the same in Models I and II, so the cost reduction of $11.3 million in Model II as compared with Model I was associated with the wheat-flour economy. The shift in the location of hard wheat milling activities in Model II increased the cost of transporting hard wheat to mills by $4 million and the cost of milling hard flour by $1 million while the cost of domestic hard flour transportation was reduced by $11 million. Soft-wheat flour milling cost increased by

TABLE XLIII

SELECTED COSTS OF MARKETING GRAIN AND FLOUR, MODELS I, II, AND III

Product and Activity	Model I	Model II	Model III
	Thousand Dollars		
Hard Wheat:			
Domestic transportation	80,091	84,248	100,955
Export transportation	149,012	145,400	155,978
Hard-Wheat Flour:			
Milling	109,594	110,896	111,208
Domestic transportation	49,985	39,457	48,592
Export transportation	11,223	12,631	11,217
Soft Wheat:			
Domestic transportation	23,251	23,004	27,305
Export transportation	39,179	40,813	42,536
Soft-Wheat Flour:			
Milling	45,336	46,330	44,878
Domestic transportation	16,064	9,373	16,878
Export transportation	561	810	603
Durum Wheat:			
Domestic transportation	13,343	13,343	13,969
Export transportation	6,211	6,211	7,594
Feed Grain:			
Domestic transportation	557,807	557,807	664,554
Export transportation	170,921	170,921	199,299
Soybeans:			
Domestic transportation	56,180	56,180	56,180
Export transportation	48,001	48,001	48,001
All Grain:			
Domestic transportation	796,721	783,412	928,433
Export transportation	425,108	424,787	465,228
Milling	154,930	157,226	156,086
Total	1,376,759	1,365,425	1,549,747

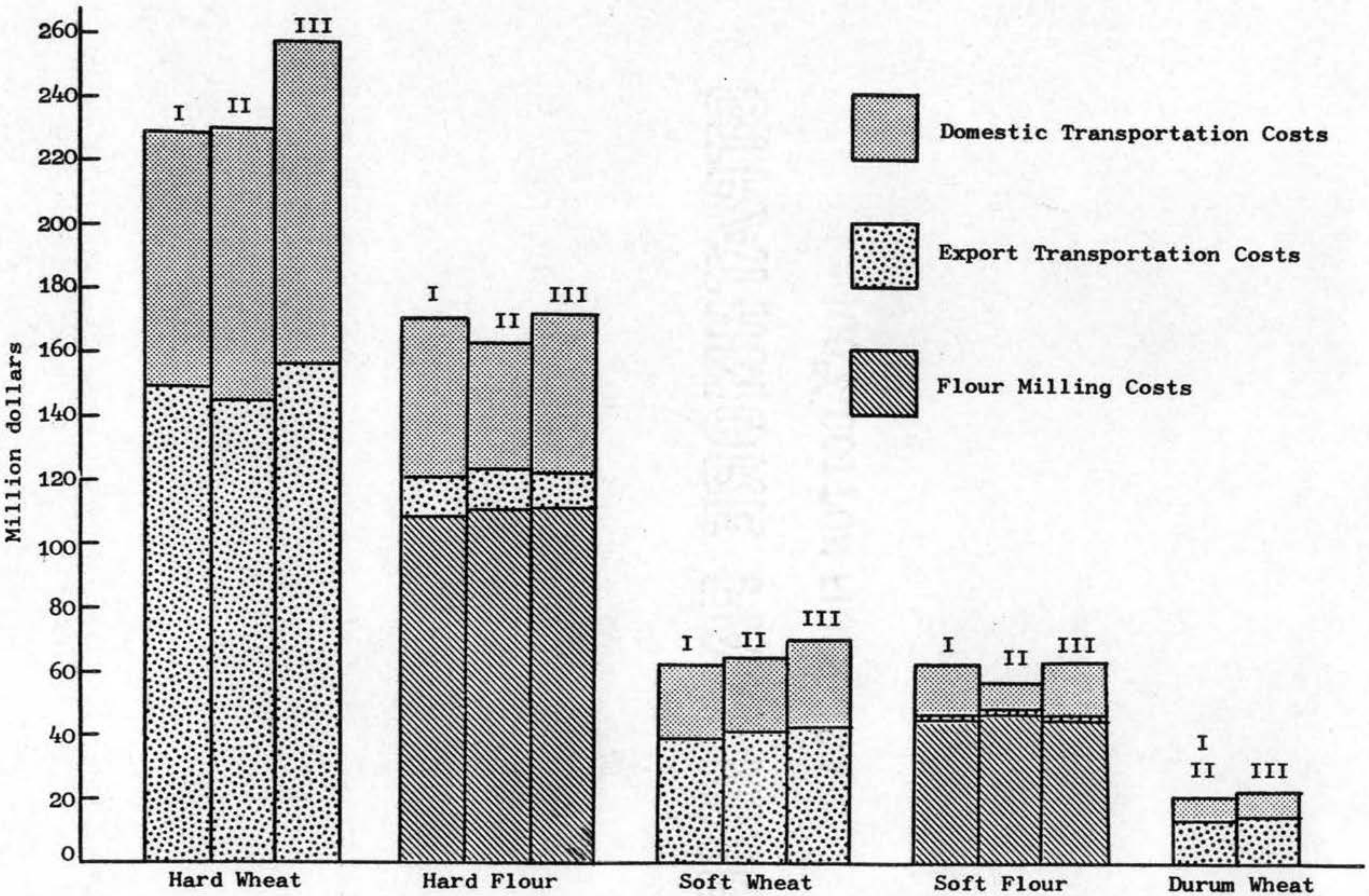


Figure 19. Selected Costs of Marketing Wheat and Flour, Models I, II, and III

$1 million, but the domestic transportation costs associated with this flour were reduced by $7 million. Thus, the relocation of milling closer to flour demand centers significantly reduced the cost of flour transportation.

The $11.3 million difference in the total cost associated with Models I and II reflects the opportunity cost of having the 1967 regional distribution of milling capacity. Such a savings certainly would not justify a relocation of milling capacity to the extent indicated in Table XXXV; however, the value of additional capacity data of Table XXVII suggests that an expansion of capacity in several regions, primarily in the Southeast, may be desirable.

A comparison of Model III costs with those of Model I, shows that requiring minimum regional inventories increased cost by $173 million. The combined costs of milling and transporting flour was $0.4 million less in Model III, so the increase was due to the additional transportation associated with moving the inventories into position. Feed grain alone accounted for $135 million or 78 percent of the increase.

FOOTNOTES

[1]National Commission on Food Marketing, *Organization and Competition in the Milling and Baking Industries*, Technical Study No. 5 (Washington, June, 1966), p. 37.

CHAPTER VI

QUARTERLY ANALYSIS

The time-staged model was formulated (Chapter IV) to determine minimum-cost flows of each grain and flour for each of four three-month quarters of the marketing year simultaneously. The primary objectives of the time-staged quarterly analysis are to study seasonal utilization of the regional storage capacity and to study the spatial flow patterns when storage capacity constraints are brought into play. A quarterly analysis is also desirable in that seasonality that existed in regional demands can be accounted for. The greatest seasonality in demands existed in the volume of grain moving to the various ports for exportation, and such variation was most striking in the case of Lake ports since the Seaway is closed during the winter months.

The original intent was to employ only time-staged models encompassing four quarters in the study. However, after three unsuccessful attempts to derive a solution to a four-quarter problem, the decision was made to employ a combination of annual and quarterly models. The difficulty in solving the quarterly problem arose primarily because of the size of the problem involved, so the size (and scope) of the problem was reduced in the following manner. Annual Model I was employed to determine the optimum type of wheat to be milled in each region and the least-cost geographical flows of hard- and soft-wheat flours. The annual data related to regional volumes of wheat milled

(Table XXVII) were prorated into quarterly regional demands for particular quantities of wheat for milling purposes by type of wheat and used for the flour milling and distribution activities in the time-staged model. For example, if annual Model I determined that 1,000,000 bushels of hard wheat was milled in Oklahoma, the time-staged model reflected this through a quarterly milling demand for hard wheat of 250,000 bushels. This procedure eliminated 884 rows from the linear programming matrix and greatly relieved the computational difficulties experienced with the larger model.

Optimum Geographical Flows

The geographical flow patterns for grain presented in the following sections minimize the total cost of satisfying the estimated quarterly regional requirements for each grain from available supplies. The quarterly flows, when aggregated, should be similar to the annual flows determined under Model I unless storage capacity constraints alter the flow patterns.

Hard Wheat

The least-cost shipment patterns for hard wheat from supply regions to flour mills and export are presented in Table XLIV by quarters. The quarterly geographical flows were similar to the annual flows. The most important divergences were found in flows from North Dakota and Montana where off-farm sales of grain greatly exceeded the available storage capacity, and this resulted in significant transshipments from these regions into Minnesota. About 9 million bushels were shipped from North Dakota to storage facilities in northern

TABLE XLIV

OPTIMUM HARD WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, TIME-STAGED MODEL

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
2	N.Y.	47	Balt.	0	367	0	0	367
3	Pa.	3	Pa.	140	140	140	140	560
		47	Balt.	5	0	0	0	5
4	Ohio	4	Ohio	0	42	0	0	42
5	Ind.	4	Ohio	157	0	0	0	157
6	Ill.	6	Ill.	201	173	0	200	574
		47	Balt.	1,097	0	0	0	1,097
7	Ill.	7	Ill.	465	465	465	113	1,508
		46	Alb.	575	178	62	0	815
		50	N.O.	98	0	0	0	98
8	Mich.	8	Mich.	0	0	0	28	28
9	Wisc.	4	Ohio	196	310	352	352	1,210
		44	Chic.	18	21	0	0	39
10	Minn.	2	N.Y.	1,110	1,110	0	475	2,695
		8	Mich.	153	153	152	124	582
11	Minn.	10	Minn.	18	18	18	18	72
		11	Minn.	0	981	981	981	2,943
		23	Ga.	14	13	13	13	53
		24	Fla.	23	23	23	23	92
		25	Ky.	61	0	0	0	61
		26	Tenn.	329	329	329	329	1,316
		27	Ala.	60	60	59	59	238
		43	Sup.	0	600	0	260	860
		49	N.Ch.	50	0	56	45	151
12	Iowa	6	Ill.	0	28	200	0	228
		13	Iowa	0	92	0	0	92
13	Iowa	13	Iowa	129	37	128	128	422
14	Mo.	7	Ill.	0	0	0	352	352
		14	Mo.	496	495	495	495	1,981
		25	Ky.	6	67	67	67	207
15	N.D.	10	Minn.	928[a]	0	0	0	928
		15	N.D.	91	91	91	91	364
		54	Port.	0	1,363	0	1,349	2,712
16	S.D.	16	S.D.	0	31	31	31	93
17	Neb.	17	Neb.	394	394	394	394	1,576
		47	Balt.	500	460	1,067	132	2,159
		48	Norf.	481	234	278	277	1,270
		50	N.O.	2,417	2,324	1,616	203	6,560
18	Kan.	2	N.Y.	0	0	1,110	634	1,744
		18	Kan.	858	858	858	858	3,432
		20	Va.	52	51	51	51	205
		21	N.C.	236	236	236	235	943
		22	S.C.	22	21	21	21	85

TABLE XLIV (Continued)

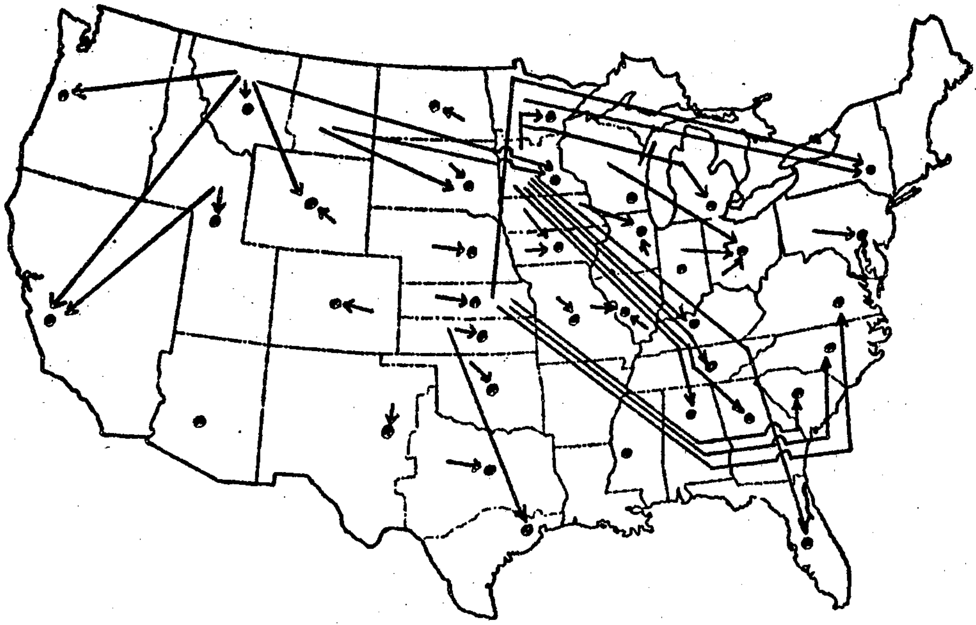
Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
19	Kan.	19	Kan.	1,138	1,138	1,138	1,138	4,552
		33	Tex.	0	0	0	182	182
		50	N.O.	500	60	0	761	1,321
		51	Hous.	0	4,150	0	0	4,150
20	Va.	48	Norf.	55	0	0	0	55
29	Ark.	50	N.O.	0	121	0	0	121
30	La.	50	N.O.	0	0	50	0	50
31	Okla.	31	Okla.	272	272	271	271	1,086
		51	Hous.	6,491	0	0	3,097	9,588
32	Tex.	32	Tex.	16	16	16	16	64
		51	Hous.	0	1,820	4,287	0	6,107
33	Tex.	33	Tex.	189	188	188	6	571
34	Tex.	34	Tex.	598	598	598	598	2,392
		51	Hous.	134	836	0	0	970
35	Mont.	11	Minn.	1,777[a]	0	0	0	1,777
		11	Minn.	981	0	0	0	981
		16	S.D.	31	0	0	0	31
		43	Sup.	494	0	0	0	494
36	Mont.	11	Minn.	2,275[a]	0	0	0	2,275
		36	Mont.	31	31	31	31	124
		37	Wyo.	14	0	0	0	14
		41	Wash.	497	0	0	0	497
		42	Cal.	259	0	0	0	259
		54	Port.	1,285	0	681	489	2,455
		55	Seat.	4	0	0	0	4
37	Wyo.	37	Wyo.	0	13	13	13	39
38	Col.	38	Col.	145	145	144	144	578
40	Idaho	40	Utah	350	350	350	349	1,399
		42	Cal.	0	259	189	259	707
		52	L.B.	34	0	0	0	34
		53	Stk.	14	3	0	0	17
		54	Port.	0	0	259	0	259
41	Wash.	41	Wash.	0	496	496	496	1,488
		54	Port.	0	0	384	0	384
		55	Seat.	367	276	102	540	1,294
42	Cal.	42	Cal.	0	0	70	0	70

[a]These quantities are transhipped from supply regions to another region for storage and subsequent shipment.

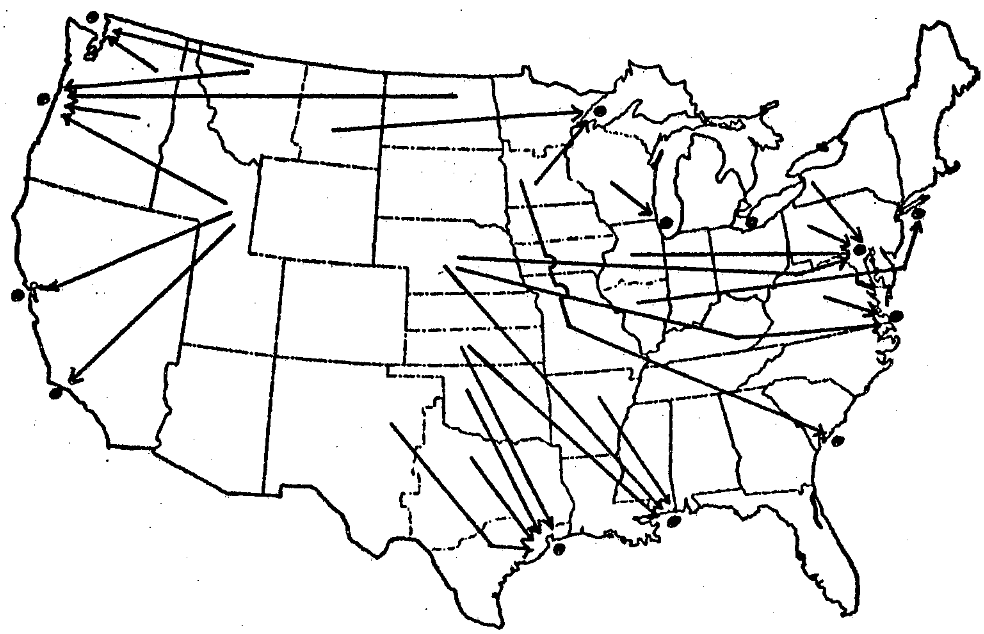
Minnesota, and approximately 40.5 million bushels were shipped from Montana to storage facilities in southern Minnesota. With these additional supplies, shipments from northern Minnesota to New York increased by about 53 percent, and southern Minnesota supplied its own millers during the last three quarters and made significant interregional shipments. Interregional shipments from Minnesota not present in the annual solution were to Alabama, Georgia, Kentucky, northern Minnesota and Duluth-Superior. Shipments to these South Central states originated in Missouri in the solution to Model I. Domestic shipments from Montana increased in the quarterly model while the volume moving from Montana to Pacific ports decreased.

Hard wheat exports from Portland that were supplied from Montana in Model I are now procured from North Dakota. This development is not unexpected since the inverse rate structure on export wheat to North Pacific coast ports from eastern Montana, the Dakota's and western Minnesota favors shipments from the most inland points. The export rail rates vary inversely with distance and are designed to provide favorable export rates from the hard spring wheat area while minimizing the effect of export rates on domestic price relationships (differentials). The aggregated flow patterns for domestic and export movements are illustrated in Figure 20.

It should be reemphasized at this point that the least-cost shipping patterns are not unique. For example, the results indicate that Oklahoma ships wheat to the port facilities at Houston in the summer and spring quarters while western Texas ships to Houston during the fall and winter quarters. Since storage rates are the same and storage capacity is not a limiting factor in either region, the quarterly



Section A. Domestic Flows



Section B. Export Flows

Figure 20. Optimum Flow Patterns for Hard Wheat, Time-Staged Model

distribution of shipments could be changed to any combination satisfying the requirements at Houston, and total costs would be the same so long as the aggregate shipments from each region to Houston remained unchanged.

Soft Wheat

The optimum soft wheat shipments for the quarterly analysis are presented in Table XLV and illustrated in Figure 21. The major interregional flows of soft-wheat are generally consistent with the results of Model I. Flows from Indiana and Idaho in the summer quarter and from Indiana in the fall appear in the quarterly solution but were absent in Model I. The increased shipping activity from these regions is a result of the available storage space filling up during the summer or fall quarters in these regions (Table LV). The flow patterns and volumes shipped to Lake, Atlantic, and Pacific ports are identical in both analyses except for a small volume shipped from South Carolina to North Charleston. Shipments to New Orleans from Indiana increased in the quarterly analysis at the expense of Illinois. Illinois, in turn, increased domestic shipments.

Durum Wheat

The optimum quarterly shipments of durum wheat are presented in Table XLVI and illustrated in Figure 22. The flows to domestic demands were predominantly an eastward flow to major processing centers in North Dakota, southern Minnesota, Wisconsin, and New York. Small shipments move westward to Washington mills. Some shipments cross in satisfying mill requirements; eastern Montana ships to southern

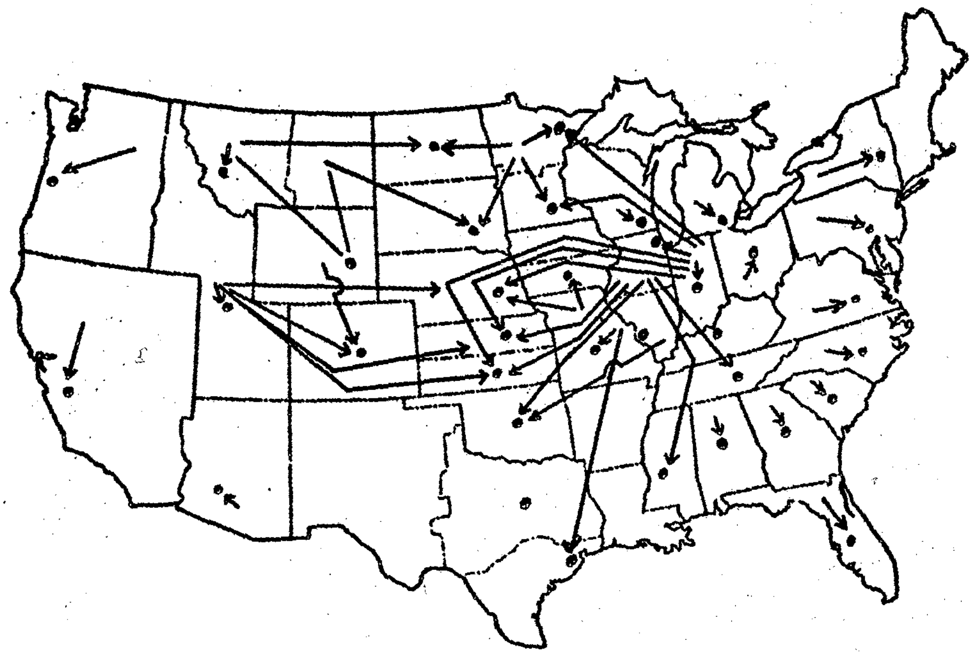
TABLE XLV

OPTIMUM SOFT WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, TIME-STAGED MODEL

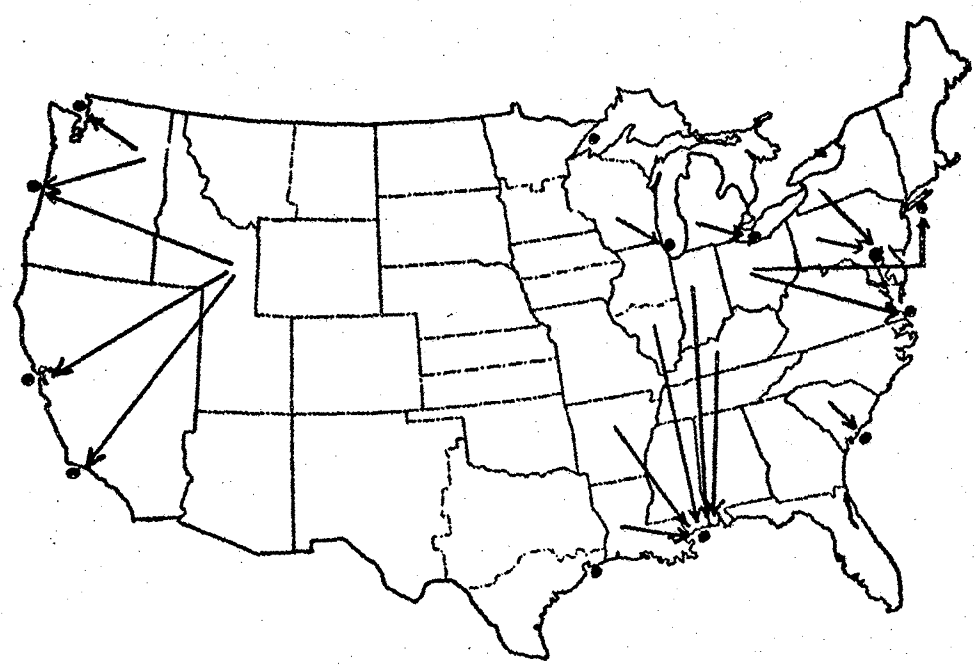
Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
2	N.Y.	2	N.Y.	290	289	289	289	1,157
		47	Balt.	200	390	200	163	953
3	Pa.	3	Pa.	362	362	362	362	1,448
		47	Balt.	0	170	0	0	170
4	Ohio	4	Ohio	554	554	554	553	2,215
		46	Alb.	56	2	180	126	364
		48	Norf.	190	93	137	327	747
5	Ind.	5	Ind.	415	415	415	415	1,660
		6	Ill.	119	119	0	0	238
		10	Minn.	14	14	0	0	28
		11	Minn.	35	0	0	0	35
		13	Iowa	32	32	0	0	64
		14	Mo.	215	0	0	0	215
		17	Neb.	0	26	0	0	26
		18	Kan.	3	30	0	0	33
		19	Kan.	0	20	0	0	20
		50	N.O.	830	0	0	0	830
6	Ill.	6	Ill.	0	0	118	118	236
		18	Kan.	0	0	30	30	60
		19	Kan.	0	0	20	20	40
		26	Tenn.	0	32	0	0	32
		28	Miss.	6	6	6	6	24
		31	Okla.	0	0	41	41	82
7	Ill.	31	Okla.	41	41	0	0	82
		50	N.O.	531	661	0	0	1,192
8	Mich.	8	Mich.	291	291	290	290	1,162
		45	Tol.	130	577	0	601	1,308
9	Wisc.	9	Wisc.	2	2	2	2	8
		44	Chic.	9	43	0	45	97
10	Minn.	10	Minn.	0	0	14	14	28
		11	Minn.	13	48	48	48	157
		15	N.D.	0	12	12	12	36
		16	S.D.	0	13	13	13	39
14	Mo.	13	Iowa	0	0	32	32	64
		14	Mo.	317	531	531	531	1,910
		17	Neb.	0	0	26	26	52
		33	Tex.	25	25	25	24	99
20	Va.	20	Va.	117	117	117	116	467
21	N.C.	21	N.C.	94	93	93	93	373
		22	S.C.	0	0	39	0	39
22	S.C.	22	S.C.	47	47	8	46	148
		49	N.Ch.	15	0	0	0	15

TABLE XLV (Continued)

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
23	Ga.	23	Ga.	44	44	44	43	175
24	Fla.	24	Fla.	14	14	14	14	56
25	Ky.	50	N.O.	0	0	0	263	263
26	Tenn.	26	Tenn.	107	75	107	107	396
27	Ala.	27	Ala.	37	36	36	36	145
28	Miss.	50	N.O.	0	0	413	251	664
29	Ark.	50	N.O.	0	0	40	871	911
30	La.	50	N.O.	0	0	180	0	180
35	Mont.	16	S.D.	13	0	0	0	13
		37	Wyo.	0	27	23	7	57
36	Mont.	15	N.D.	12	0	0	0	12
		36	Mont.	13	13	13	13	52
		37	Wyo.	27	0	0	19	46
37	Wyo.	37	Wyo.	0	0	4	0	4
		38	Col.	0	3	3	3	9
39	Ariz.	39	Ariz.	12	12	12	12	48
40	Idaho	17	Neb.	26	0	0	0	26
		18	Kan.	27	0	0	0	27
		19	Kan.	20	0	0	0	20
		38	Col.	4	0	0	0	4
		40	Utah	51	50	50	50	201
		52	L.B.	8	0	0	0	8
		53	Stk.	12	0	0	0	12
		54	Port.	0	0	82	0	82
41	Wash.	41	Wash.	177	177	177	176	707
		54	Port.	1,856	2,820	2,264	2,283	9,223
		55	Seat.	580	591	556	627	2,354
42	Cal.	42	Cal.	262	262	262	262	1,048



Section A. Domestic Flows



Section B. Export Flows

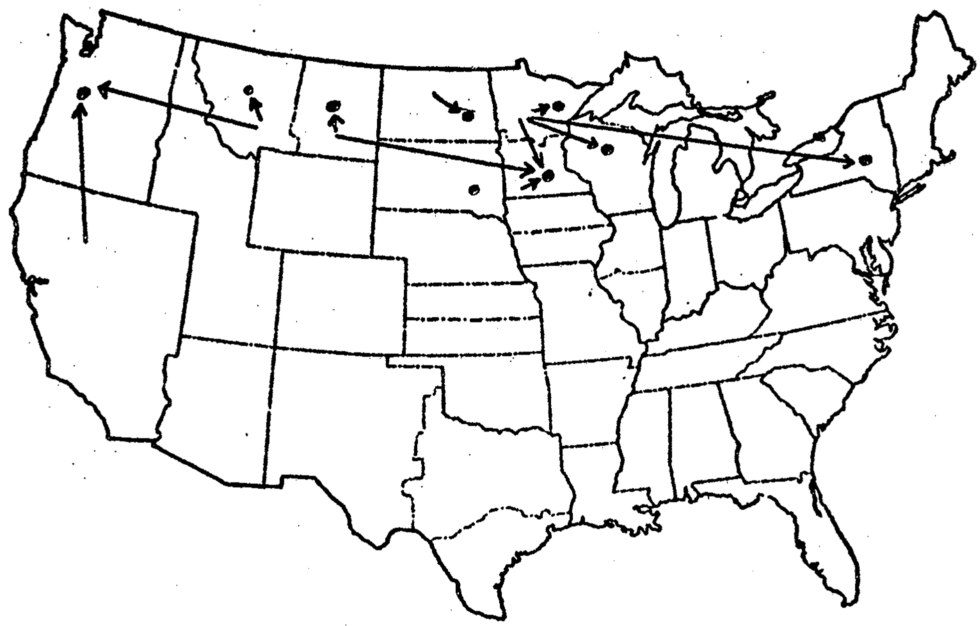
Figure 21. Optimum Flow Patterns for Soft Wheat, Time-Staged Model

TABLE XLVI

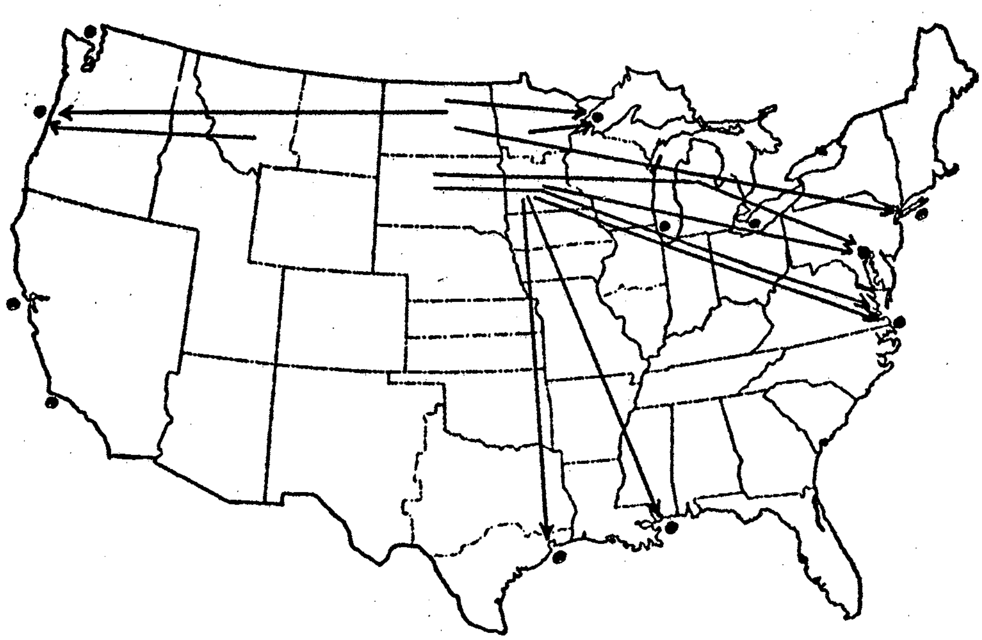
OPTIMUM DURUM WHEAT SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, TIME-STAGED MODEL

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
10	Minn.	2	N.Y.	60	60	60	60	240
		9	Wisc.	127	127	127	127	508
		10	Minn.	0	0	0	11	11
		11	Minn.	0	136	189	234	559
		43	Sup.	0	409	0	0	409
11	Minn.	11	Minn.	0	98	45	0	143
		47	Balt.	0	0	0	58	58
		48	Norf.	0	160	336	155	651
		50	N.O.	210	94	328	97	729
		51	Hous.	0	0	61	9	70
15	N.D.	15	N.D.	53	53	53	378	537
		41	Wash.	0	44	0	91	135
		43	Sup.	728	1,048	0	564	2,340
		46	Alb.	83	0	0	0	83
		54	Port.	0	10	6	12	28
16	S.D.	16	S.D.	0	0	0	20	20
		47	Balt.	0	0	231	0	231
		48	Norf.	0	0	165	0	165
35	Mont.	11	Minn.	51[a]	0	0	0	51
		11	Minn.	234	0	0	0	234
		35	Mont.	0	0	0	12	12
36	Mont.	36	Mont.	0	0	0	8	8
		41	Wash.	199[a]	0	0	0	199
		54	Port.	24	0	0	0	24
41	Wash.	41	Wash.	91	17	91	0	199
42	Cal.	41	Wash.	0	30	0	0	30

[a]These quantities are transhipped from supply regions to another region for storage and subsequent shipment.



Section A. Domestic Flows



Section B. Export Flows

Figure 22. Optimum Flow Patterns for Durum Wheat, Time-Staged Model

Minnesota while North Dakota ships durum wheat to Washington. This "cross-hauling" resulted because storage space was filled in Montana and Washington at the end of summer which prevented transhipment from eastern Montana to Washington. Consequently, the durum in eastern Montana moved to Minnesota. In subsequent quarters, additional quantities were shipped to Washington from North Dakota. This appears to be inefficient, but given the available storage capacity and considering all grains simultaneously, it was the least costly means of satisfying the demands.

The flows to export are essentially the same as determined in Model I. The main difference is the fact that northern Minnesota shipped approximately four million bushels to Duluth-Superior. These needs are procured entirely from North Dakota in the annual analysis.

Feed Grain

Regional requirements for feed, seed and industrial uses were aggregated to arrive at quarterly demands in each region. Quarterly estimates for feed and seed were combined with 25 percent of the estimated annual use for industrial purposes to arrive at total disappearance of feed grain by region and by quarter. From an analytical standpoint, it would be desirable to specify regional demands by type of feed grain for seed and industrial use; however, this was not done because of computational considerations.

The least cost quarterly distribution pattern for feed grain is presented in Table XLVII, and interregional flows are illustrated in Figures 23 and 24. It is evident that interregional movement of feed grain is much greater than for other grains. The information of

TABLE XLVII

OPTIMUM FEED GRAIN SHIPMENTS FROM SUPPLY REGIONS TO DEMAND REGIONS, TIME-STAGED MODEL

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
				10,000 Bu.				
1	N.E.	1	N.E.	134	0	79	0	213
2	N.Y.	2	N.Y.	0	0	0	1,618	1,618
3	Pa.	3	Pa.	1,921	0	2,748	0	4,669
4	Ohio	2	N.Y.	1,296	0	0	0	1,296
		3	Pa.	2,225	3,561	2,243	2,708	10,737
		4	Ohio	513	604	642	739	2,498
		20	Va.	1,136	1,219	0	551	2,906
5	Ind.	1	N.E.	1,862	2,423	2,515	2,020	8,820
		2	N.Y.	572	2,194	2,325	390	5,481
		3	Pa.	0	1,374	0	1,568	2,942
		5	Ind.	1,749	1,925	1,997	1,952	7,623
		46	Alb.	0	55	0	0	55
		47	Balt.	0	1,125	0	0	1,125
		48	Norf.	0	327	0	0	327
6	Ill.	23	Ga.	2,820	4,341	5,233	2,263	14,657
		24	Fla.	251	490	1,106	856	2,703
		27	Ala.	0	1,934	3,023	2,785	7,742
		28	Miss.	0	0	156	1,868	2,024
		30	La.	0	454	0	0	454
		46	Alb.	0	0	302	39	341
		47	Balt.	164	0	1,135	225	1,524
		48	Norf.	346	460	647	238	1,691
		50	N.O.	4,015	724	10,896	0	15,635
7	Ill.	20	Va.	0	0	1,697	940	2,637
		21	N.C.	2,507	587	3,452	2,998	9,544
		22	S.C.	375	152	827	650	2,004
		27	Ala.	2,407	1,295	0	0	3,702
8	Mich.	3	Pa.	0	0	281	0	281
		8	Mich.	804	837	851	980	3,472
		45	Tol.	323	1,090	0	733	2,146
9	Wisc.	9	Wisc.	1,345	1,398	1,418	1,891	6,052
		44	Chic.	0	1,414	0	81	1,495
10	Minn.	11	Minn.	0	517	517	517	1,551
		43	Sup.	2,533	2,293	0	1,742	6,568
11	Minn.	30	La.	0	0	758	579	1,337
		50	N.O.	4,859	9,157	0	8,180	22,196
12	Iowa	6	Ill.	336	2,768	2,919	2,752	8,775
		12	Iowa	549	673	722	807	2,751
		26	Tenn.	1,924	362	2,249	1,899	6,434
13	Iowa	6	Ill.	2,348	0	0	0	2,348
		7	Ill.	1,819	1,905	2,121	1,927	7,772
		13	Iowa	2,724	2,999	3,558	2,847	12,128

TABLE XLVII (Continued)

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
						10,000 Bu.		
13	Iowa	14	Mo.	2,945	3,471	3,782	3,006	13,204
		24	Fla.	464	0	0	0	464
		29	Ark.	91	0	2,222	0	2,313
14	Mo.	25	Ky.	0	0	1,500	1,101	2,601
		29	Ark.	0	3,804	1,863	2,365	8,032
15	N.D.	11	Minn.	12,103[a]	0	0	0	12,103
		11	Minn.	517	0	0	0	517
		15	N.D.	4	4	4	4	16
16	S.D.	16	S.D.	66	82	736	193	1,077
		44	Chic.	2,630	652	0	879	4,161
17	Neb.	17	Neb.	1,660	1,990	2,302	1,746	7,698
		38	Col.	0	100	0	0	100
		42	Cal.	2,189	5,475	0	0	7,664
18	Kan.	18	Kan.	419	479	555	463	1,916
		42	Cal.	0	0	1,604	0	1,604
19	Kan.	19	Kan.	211	228	267	235	941
		31	Okla.	931	943	1,004	799	3,677
20	Va.	20	Va.	398	545	182	0	1,125
21	N.C.	21	N.C.	533	3,009	393	0	3,935
22	S.C.	22	S.C.	320	621	0	0	941
		49	N.Ch.	2	12	0	16	30
23	Ga.	23	Ga.	1,231	539	0	1,763	3,533
24	Fla.	24	Fla.	141	542	0	0	683
		49	N.Ch.	0	0	6	4	10
25	Ky.	25	Ky.	1,311	1,440	0	206	2,957
26	Tenn.	26	Tenn.	0	1,782	0	0	1,782
27	Ala.	27	Ala.	393	147	596	0	1,136
28	Miss.	28	Miss.	199	409	0	0	608
29	Ark.	29	Ark.	0	0	0	740	740
30	La.	30	La.	592	252	0	0	844
31	Okla.	29	Ark.	3,041	0	0	0	3,041
32	Tex.	32	Tex.	778	651	699	584	2,712
		51	Hous.	6,208	0	3,542	4,461	14,211
		52	L.B.	605	1,340	1,107	0	3,052
		53	Stk.	94	311	391	128	924
33	Tex.	33	Tex.	1,223	1,347	1,429	1,148	5,147
		51	Hous.	406	3,175	0	0	3,581
34	Tex.	28	Miss.	1,685	1,859	2,278	0	5,822
		34	Tex.	1,829	2,072	2,218	1,718	7,837
		51	Hous.	0	1,398	0	0	1,398
35	Mont.	35	Mont.	4	4	4	131	143
		36	Mont.	0	10	0	0	10
		37	Wyo.	27	0	0	0	27
		54	Port.	0	26	0	0	26
36	Mont.	36	Mont.	8	0	11	265	284

TABLE XLVII (Continued)

Supply Region		Demand Region		Quantity Shipped				
				Summer	Fall	Winter	Spring	Total
						10,000 Bu.		
36	Mont.	40	Utah	517	0	0	0	517
		41	Wash.	1,222	0	0	0	1,222
		54	Port.	40	290	637	359	1,326
		55	Seat.	262	0	0	0	262
37	Wyo.	37	Wyo.	0	33	36	79	148
		38	Col.	124	0	0	0	124
38	Col.	38	Col.	554	791	994	743	3,082
39	Ariz.	39	Ariz.	292	358	412	293	1,355
		52	L.B.	224	0	131	777	1,132
40	Idaho	38	Col.	106	0	0	0	106
		40	Utah	0	621	810	519	1,950
		41	Wash.	0	0	138	0	138
41	Wash.	41	Wash.	0	1,475	1,656	1,224	4,355
		54	Port.	0	188	0	0	188
		55	Seat.	0	0	6	10	16
42	Cal.	42	Cal.	2,338	0	4,604	4,534	11,476

[a]These quantities are transhipped from supply regions to another region for storage and subsequent shipment.

Figure 23. Optimum Flow Pattern for Feed Grain to Domestic Destinations, Time-Staged Model

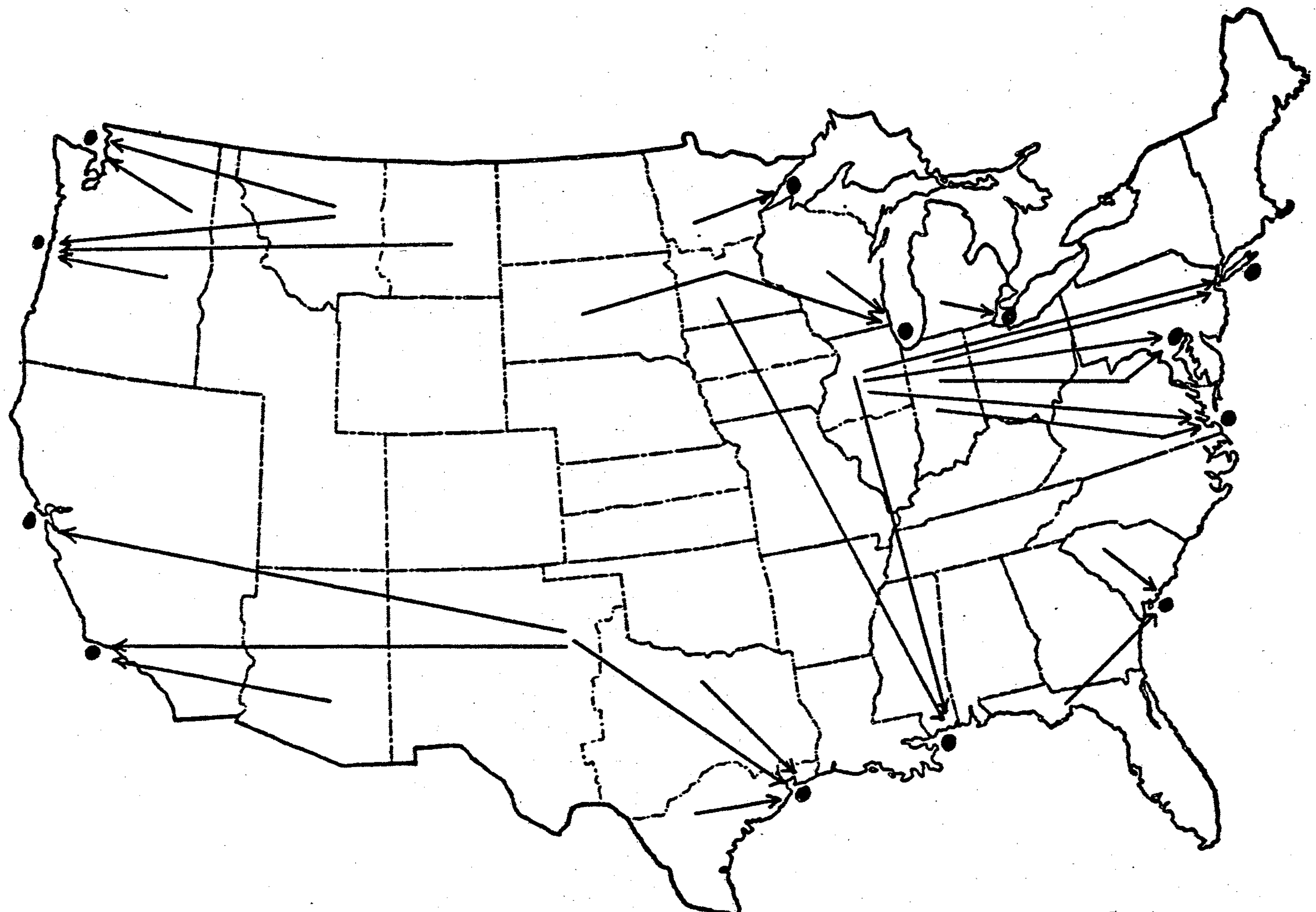


Figure 24. Optimum Flow Pattern for Feed Grain to Port Destinations,
Time-Staged Model

Table XLVII indicates that New England consumed 134 units of its supplies during the summer quarter and stored the remaining 79 units for consumption during the winter. New England's requirements in excess of local supplies were procured from Indiana. In general, the supply regions for the deficit Northeast were Ohio and Indiana, and deficits in the South Atlantic and South Central regions were supplied by Illinois, Iowa, Missouri, and Kansas. The sizable feed grain deficit of California was satisfied with shipments from Nebraska and Kansas.

For the most part, the shipment pattern determined by the quarterly analysis was very similar to that of Model I. Differences which existed were related to storage capacity constraints. For example, in the quarterly analysis, Indiana shipped some feed grain to Atlantic ports during the fall quarter. These needs were supplied by northern Illinois in the annual model. Shipments from Illinois to Florida were increased which reduced shipments from Iowa to Florida. Iowa in turn shipped grain to Arkansas, satisfying demands previously supplied by Kansas. This example serves to illustrate how an initial alteration in a shipment pattern can set in motion a whole series of adjustments in the optimum shipment pattern of a spatial equilibrium analysis.

Soybeans

Optimum domestic soybean flows are presented in Table XLVIII. The distribution pattern for soybeans was characterized by very limited interregional shipments with most of the activity associated with destination points located near the adjacent supply regions. For example, the shipments from the West North Central to the East North Central in the third and fourth quarters are shipments from Missouri to East

TABLE XLVIII

OPTIMUM SOYBEAN SHIPMENTS FROM SUPPLY REGIONS TO DOMESTIC DEMAND REGIONS, TIME-STAGED MODEL

Origin[a]	Destination[a]: South Atlantic	East North Central	West North Central	East South Central	West South Central
	10,000 Bu.				
	Summer				
South Atlantic	234	0	0	0	0
East North Central	266	5,022	0	328	0
West North Central	0	0	3,860	0	0
East South Central	206	0	0	1,096	0
West South Central	0	0	0	0	741
	Fall				
South Atlantic	861	0	0	0	0
East North Central	0	6,125	0	582	0
West North Central	0	0	4,822	0	0
East South Central	0	0	0	1,154	0
West South Central	0	0	0	0	904
	Winter				
South Atlantic	883	0	0	0	0
East North Central	0	5,772	0	283	0
West North Central	0	504	4,786	0	0
East South Central	0	0	0	1,497	0
West South Central	0	0	0	0	925
	Spring				
South Atlantic	1,017	0	0	0	0
East North Central	0	4,804	0	312	0
West North Central	0	1,715	5,457	0	0
East South Central	0	0	0	1,750	0
West South Central	0	0	0	0	1,224

[a]Individual shipments were aggregated to standard regions used by the Bureau of the Census to avoid disclosure of individual firm capacities.

St. Louis (the destination for southern Illinois).

Optimum quarterly soybean shipments to ports for export are presented in Table XLIX and illustrated in Figure 25. In general, export requirements were satisfied from nearby regions. Arkansas was the most important of all regions in terms of volume shipped to export points, and Illinois and Arkansas each shipped in excess of 50 million bushels to port locations.

Optimum Utilization of Storage Capacity

Optimum utilization of storage capacity refers to the specification of both the type and volume of grain or soybeans stored in each region by quarter, given the existing regional grain storage capacity. The volumes were determined simultaneously with the optimum geographical flows of grain presented above. Data of this nature were not available from the annual model.

Optimum Quarterly Inventories

The inventory information should be interpreted as inventory positions that should be maintained by quarters if the optimum distribution patterns are to be achieved. However, this should not be interpreted as implying that these regional distributions of stocks will actually exist in reality, because one marketing year is not isolated from the following year. For example, the results indicate that North Dakota and South Dakota would have about 143 million bushels of hard wheat in inventory as of June 30. In reality, a large proportion of these stocks would have moved out to primary markets by the end of the year so that the local facilities could handle the new crop as it moves

TABLE XLIX

OPTIMUM SOYBEAN SHIPMENTS FROM SUPPLY REGIONS TO EXPORT DEMAND REGIONS, TIME-STAGED MODEL

Supply Region		Demand Region		Quantity Shipped Summer	Fall	Winter	Spring	Total
					10,000 Bu.			
2	N.Y.	45	Tol.	0	4	0	0	4
3	Pa.	47	Balt.	0	132	299	23	454
4	Ohio	45	Tol.	0	1,164	0	0	1,164
5	Ind.	44	Chic.	487	882	0	187	1,556
		45	Tol.	216	0	0	0	216
7	Ill.	47	Balt.	6	0	0	0	6
		48	Norf.	5	0	0	0	5
		50	N.O.	1,450	3,638	0	0	5,088
8	Mich.	45	Tol.	70	390	0	620	1,080
9	Wisc.	44	Chic.	0	0	0	329	329
10	Minn.	43	Sup.	45	0	0	0	45
11	Minn.	43	Sup.	471	126	0	231	828
20	Va.	47	Balt.	0	117	0	0	117
21	N.C.	48	Norf.	0	215	148	60	423
		49	N.Ch.	1	0	0	0	1
22	S.C.	49	N.Ch.	27	291	340	213	871
23	Ga.	50	N.O.	0	605	0	0	605
24	Fla.	50	N.O.	0	0	205	0	205
27	Ala.	50	N.O.	0	3	0	0	3
28	Miss.	50	N.O.	85	2,104	0	1,261	3,450
29	Ark.	50	N.O.	0	0	2,634	3,260	5,894
		51	Hous.	0	0	52	4	56
30	La.	50	N.O.	0	0	2,398	0	2,398
		51	Hous.	0	87	0	0	87
33	Tex.	51	Hous.	0	3	0	0	3

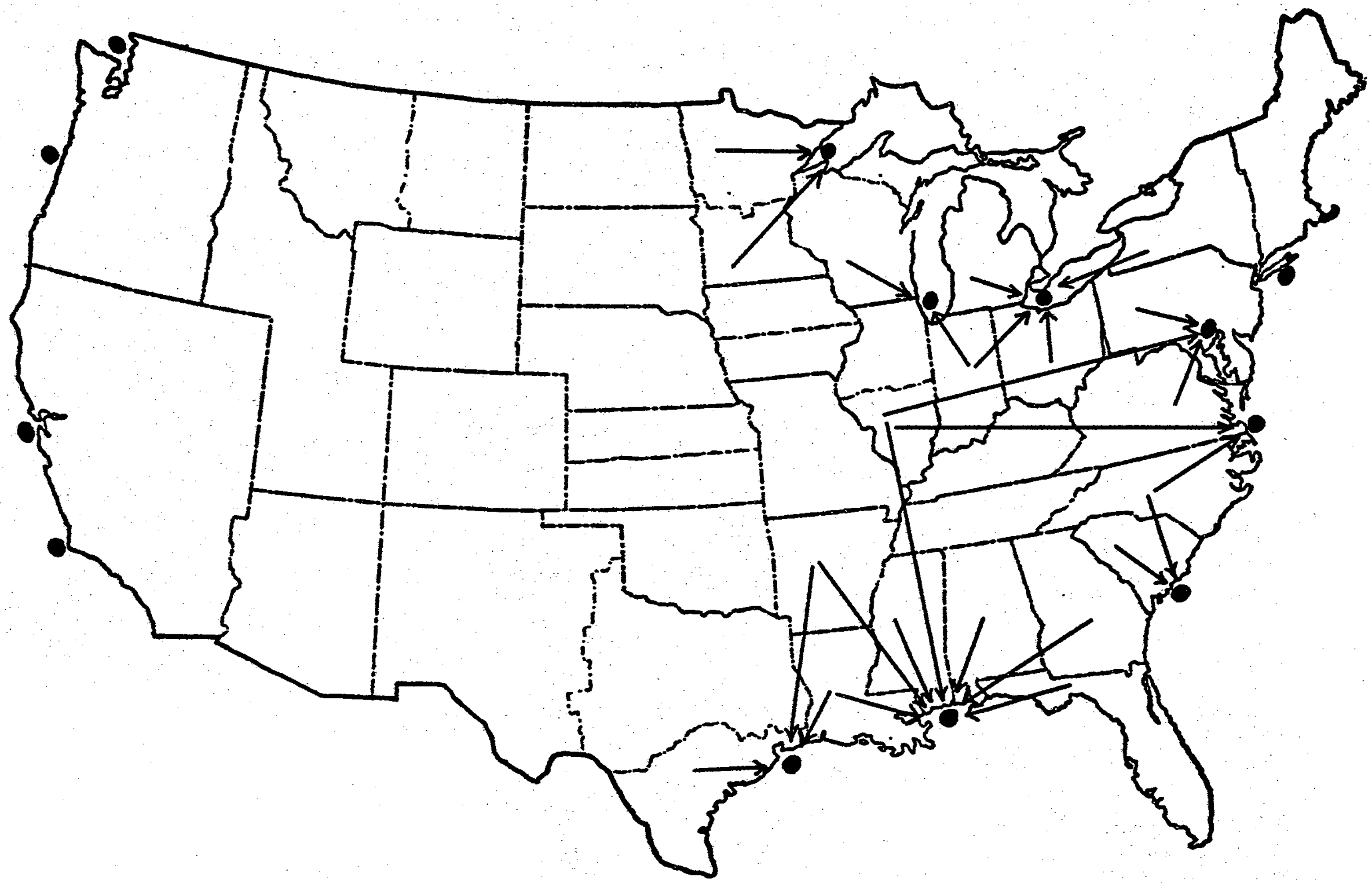


Figure 25. Optimum Flow Pattern for Soybeans to Port Destinations, Time-Staged Model

off-farm. In addition, processors in deficit regions generally maintain a working inventory in excess of immediate needs to ensure a continuous operation. Thus, the ending inventories may be more widely distributed than these results indicate.

Given the estimated supply and demand data for each quarter, the quarterly inventories were derived in the model and are presented by type of grain in the following tables: hard wheat, Table L; soft wheat, Table LI; durum wheat, Table LII; feed grain, Table LIII; and soybeans, Table LIV. Each table includes figures showing the level of stocks of the particular grain that was in storage in each region at the end of each quarter.

Utilization of Inland Facilities

The five grains included in the model competed for the available storage capacity of each region at the end of each quarter. The extent to which inland storage capacity of each region was utilized by the five grains is presented by quarter in Table LV. The data show the proportion of estimated capacity filled with inventories at the end of each quarter. The regional demands for storage capacity were the greatest at the end of the fall quarter, and the capacity of 15 regions was completely filled. The inventories in 34 regions occupied 50 percent or more of the storage capacity. On March 31, only nine regions had less than 25 percent of the available capacity occupied.

The information of Table LV indicates that several regions had excess storage capacity. The level of aggregation involved in this study makes it impossible to specify the absolute amount of storage capacity needed in each region since the size and distribution of firms

TABLE L

OPTIMUM REGIONAL INVENTORIES OF HARD WHEAT, TIME-STAGED MODEL

Storage Region		Quantity Stored			
		Summer	Fall	Winter	Spring
			10,000 Bu.		
1	N.E.	0	0	0	0
2	N.Y.	367	0	0	0
3	Pa.	420	280	140	0
4	Ohio	42	0	0	0
5	Ind.	0	0	0	0
6	Ill.	373	200	200	0
7	Ill.	1,283	640	113	0
8	Mich.	28	28	28	0
9	Wisc.	1,035	704	352	0
10	Minn.	2,087	824	672	0
11	Minn.	5,321	3,279	1,782	0
12	Iowa	320	200	0	0
13	Iowa	293	256	128	0
14	Mo.	2,038	1,476	914	0
15	N.D.	12,169	10,715	10,624	9,037
16	S.D.	6,080	6,037	6,006	5,910
17	Neb.	7,773	4,361	1,006	0
18	Kan.	12,623	11,437	9,161	6,728
19	Kan.	12,132	6,784	5,646	3,565
20	Va.	0	0	0	0
21	N.C.	0	0	0	0
22	S.C.	0	0	0	0
23	Ga.	0	0	0	0
24	Fla.	0	0	0	0
25	Ky.	0	0	0	0
26	Tenn.	0	0	0	0
27	Ala.	0	0	0	0
28	Miss.	0	0	0	0
29	Ark.	121	0	0	0
30	La.	85	50	0	0
31	Okla.	3,911	3,639	3,368	0
32	Tex.	6,155	4,319	16	0
33	Tex.	382	194	6	0
34	Tex.	2,630	1,196	598	0
35	Mont.	924	924	924	904
36	Mont.	1,297	1,266	554	0
37	Wyo.	443	430	417	404
38	Col.	4,400	4,255	4,111	3,967
39	Ariz.	21	21	21	21
40	Idaho	2,031	1,419	621	0
41	Wash.	2,790	2,018	1,036	0
42	Cal.	70	70	0	0

TABLE LI

OPTIMUM REGIONAL INVENTORIES OF SOFT WHEAT, TIME-STAGED MODEL

Storage Region		Quantity Stored			
		Summer	Fall	Winter	Spring
			10,000 Bu.		
1	N.E.	0	0	0	0
2	N.Y.	1,620	941	452	0
3	Pa.	1,507	975	613	251
4	Ohio	3,377	2,728	1,857	851
5	Ind.	2,051	1,395	980	565
6	Ill.	622	584	369	154
7	Ill.	702	0	0	0
8	Mich.	2,523	1,655	1,365	474
9	Wisc.	463	418	416	369
10	Minn.	247	174	87	0
11	Minn.	0	0	0	0
12	Iowa	0	0	0	0
13	Iowa	0	0	0	0
14	Mo.	1,783	1,227	613	0
15	N.D.	0	0	0	0
16	S.D.	0	0	0	0
17	Neb.	0	0	0	0
18	Kan.	0	0	0	0
19	Kan.	0	0	0	0
20	Va.	369	233	116	0
21	N.C.	344	225	93	0
22	S.C.	112	54	46	0
23	Ga.	141	87	43	0
24	Fla.	47	28	14	0
25	Ky.	533	511	511	248
26	Tenn.	313	214	107	0
27	Ala.	121	72	36	0
28	Miss.	744	664	251	0
29	Ark.	911	911	871	0
30	La.	180	180	0	0
31	Okla.	0	0	0	0
32	Tex.	0	0	0	0
33	Tex.	0	0	0	0
34	Tex.	0	0	0	0
35	Mont.	356	329	306	299
36	Mont.	58	45	32	0
37	Wyo.	13	10	3	0
38	Col.	0	0	0	0
39	Ariz.	65	53	41	29
40	Idaho	1,910	1,860	1,728	1,678
41	Wash.	9,671	6,083	3,086	0
42	Cal.	786	524	262	0

TABLE LII

OPTIMUM REGIONAL INVENTORIES OF DURUM WHEAT, TIME-STAGED MODEL

Storage Region		Quantity Stored			
		Summer	Fall	Winter	Spring
			10,000 Bu.		
10	Minn.	1,540	808	432	0
11	Minn.	1,441	1,089	319	0
15	N.D.	5,485	4,330	4,271	3,226
16	S.D.	416	416	20	0
35	Mont.	12	12	12	0
36	Mont.	8	8	8	0
41	Wash.	108	91	0	0

TABLE LIII

OPTIMUM REGIONAL INVENTORIES OF FEED GRAIN, TIME-STAGED MODEL

Storage Region		Quantity Stored			
		Summer	Fall	Winter	Spring
			10,000 Bu.		
1	N.E.	63	79	0	0
2	N.Y.	1,309	1,618	1,618	0
3	Pa.	231	2,748	0	0
4	Ohio	0	6,883	3,998	0
5	Ind.	0	12,767	5,930	0
6	Ill.	0	30,772	8,274	0
7	Ill.	0	10,564	4,588	0
8	Mich.	1,154	2,845	1,713	0
9	Wisc.	3,895	3,390	1,972	0
10	Minn.	2,740	4,675	4,158	1,899
11	Minn.	15,028	9,517	8,759	0
12	Iowa	3,781	11,348	5,458	0
13	Iowa	2,530	19,463	7,780	0
14	Mo.	3,807	6,829	3,466	0
15	N.D.	0	422	418	414
16	S.D.	7,762	8,261	7,525	6,453
17	Neb.	16,385	36,485	34,183	32,437
18	Kan.	4,710	11,321	9,162	8,699
19	Kan.	2,463	5,639	4,368	3,334
20	Va.	0	182	0	0
21	N.C.	347	393	0	0
22	S.C.	0	16	16	0
23	Ga.	0	1,763	1,763	0
24	Fla.	0	10	4	0
25	Ky.	1,646	206	206	0
26	Tenn.	400	0	0	0
27	Ala.	0	596	0	0
28	Miss.	0	0	0	0
29	Ark.	335	740	740	0
30	La.	39	0	0	0
31	Okla.	0	0	0	0
32	Tex.	19,539	24,913	19,174	14,001
33	Tex.	5,229	2,577	1,148	0
34	Tex.	8,739	6,214	1,718	0
35	Mont.	1,790	1,877	1,813	1,682
36	Mont.	1,460	1,272	624	0
37	Wyo.	115	115	79	0
38	Col.	1,069	1,737	743	0
39	Ariz.	923	1,613	1,070	0
40	Idaho	2,009	1,467	519	0
41	Wash.	4,446	2,896	1,234	0
42	Cal.	6,690	9,138	4,534	0

TABLE LIV

OPTIMUM REGIONAL INVENTORIES OF SOYBEANS, TIME-STAGED MODEL

Storage Region		Quantity Stored			
		Summer	Fall	Winter	Spring
		10,000 Bu.			
1	N.E.	0	0	0	0
2	N.Y.	0	0	0	0
3	Pa.	0	405	106	83
4	Ohio	0	3,720	2,489	1,160
5	Ind.	742	2,643	1,457	0
6	Ill.	3,074	6,155	2,517	0
7	Ill.	546	0	0	0
8	Mich.	0	620	620	0
9	Wisc.	10	329	329	0
10	Minn.	572	1,971	1,971	1,971
11	Minn.	0	4,538	3,582	2,269
12	Iowa	0	5,107	4,323	3,431
13	Iowa	0	7,022	5,190	3,223
14	Mo.	3,555	7,267	6,110	3,552
15	N.D.	307	362	362	362
16	S.D.	456	674	674	674
17	Neb.	53	2,244	2,175	2,051
18	Kan.	0	739	580	402
19	Kan.	0	740	371	0
20	Va.	0	513	292	0
21	N.C.	0	1,144	528	0
22	S.C.	0	1,395	873	441
23	Ga.	0	50	38	0
24	Fla.	0	205	0	0
25	Ky.	0	177	177	0
26	Tenn.	0	1,962	919	0
27	Ala.	0	453	229	0
28	Miss.	0	1,916	1,686	0
29	Ark.	674	7,975	4,380	0
30	La.	440	2,398	0	0
31	Okla.	125	251	235	127
32	Tex.	137	334	334	315
33	Tex.	0	0	0	0
34	Tex.	5	23	23	22

TABLE LV

UTILIZATION OF INLAND STORAGE CAPACITY BY REGION, TIME-STAGED MODEL

Storage Region		Estimated Capacity	Proportion of Capacity Used as of			
			Sept. 30	Dec. 31	March 31	June 30
		10,000 Bu.	Percent			
1	N.E.	427	15	18	0	0
2	N.Y.	5,492	60	47	38	0
3	Pa.	4,408	41	100	21	8
4	Ohio	13,371	26	100	63	16
5	Ind.	16,805	17	100	50	3
6	Ill.	38,287	10	98	30	1
7	Ill.	11,204	23	100	42	0
8	Mich.	5,882	65	89	63	10
9	Wisc.	6,209	87	78	49	6
10	Minn.	8,488	86	100	88	42
11	Minn.	28,680	76	78	50	8
12	Iowa	20,479	20	81	48	17
13	Iowa	38,231	7	70	34	8
14	Mo.	20,178	55	83	55	18
15	N.D.	17,889	100	88	87	72
16	S.D.	15,388	96	100	92	85
17	Neb.	57,153	42	75	65	60
18	Kan.	50,415	34	46	37	32
19	Kan.	37,322	39	36	28	19
20	Va.	928	40	100	44	0
21	N.C.	2,730	24	65	23	0
22	S.C.	1,465	8	100	64	30
23	Ga.	1,900	7	100	97	0
24	Fla.	293	16	83	6	0
25	Ky.	2,334	93	38	38	11
26	Tenn.	3,852	18	56	27	0
27	Ala.	1,121	11	100	24	0
28	Miss.	2,568	29	100	74	0
29	Ark.	10,545	19	91	57	0
30	La.	2,628	28	100	0	0
31	Okla.	23,600	17	16	15	1
32	Tex.	57,226	45	52	34	25
33	Tex.	9,722	58	28	12	0
34	Tex.	21,066	54	35	11	0
35	Mont.	3,082	100	100	99	94
36	Mont.	2,823	100	92	43	0
37	Wyo.	644	89	86	78	63
38	Col.	8,333	66	72	58	48
39	Ariz.	1,600	58	100	65	3
40	Idaho	5,950	100	80	48	28
41	Wash.	17,015	100	65	32	0
42	Cal.	9,732	78	100	49	0

making up the total capacity are ignored. For example, results may indicate a very low utilization in a region when in fact there may be a shortage of capacity in a particular locality. However, the problem of firm size and distribution is beyond the scope of this study. Even though the results are limited in this sense, some important conclusions may be drawn.

Eleven of the 42 regions had a utilization percentage of less than 75 in the peak quarter, and this fact suggests that these regions had excess storage capacity. The most serious excess capacity problems were found in Kansas, Oklahoma, and Texas. In addition, the utilization percentage was low in New England and New York. The three Southwestern states experienced sizable increases in storage capacity in the late 1950's and early 1960's when wheat stocks increased to record levels. The carryover of wheat declined during the 1960's leaving the storage industry in the Southwest in an overexpanded position. A 1965 survey of the Oklahoma-Texas grain marketing industries found evidence of this.[1] Thirty grain handling and storage firms were reported closed when the survey was taken, and 80 percent of these closings had taken place during 1963-1965. Over one-half of these firms were storage firms, and several others were reported empty at the time of the survey. This trend is likely to continue unless the United States has a significant increase in wheat carryover stocks in the near future.

New York also had a low level of utilization (Table LV). Heid reported that in 1962 about 32 percent (29 million bushels) of the terminal storage capacity in the Northeast was unused.[2] This had increased from 15 percent in 1957. These data also included port terminal facilities in the Northeast which will be considered in the next section.

Downward adjustments in storage capacity are likely to come about rather slowly in these regions. There are several factors that impede exit of firms from the industry. First a very high proportion of the cost associated with the operation of a grain storage firm is fixed and does not vary with volume. Hence, the relatively low variable cost proportion can be covered with a low level of utilization. Second, many of the elevators are relatively new, and alternative uses for the facilities are almost nonexistent. Therefore, the salvage value is very low compared with the fixed investment in plant and equipment.

From the standpoint of national interest, it may be desirable to maintain this excess capacity in the grain storage industry so that capacity would be available in the event that a rapid build-up of emergency stocks becomes desirable. Thus, to ensure the livelihood of these storage firms, policy officials could store government stocks that are desirable for national defense reasons in these areas of low utilization. Such an inventory policy would free storage capacity in the North Central Region (other than that located in Kansas) that presently may be used for this purpose, but is needed for commercial marketing activities. Both areas of low utilization are located near major ports, and the inventories would be readily available if relief shipments to foreign countries were needed on short notice.

Utilization of Port Facilities

Operation of port elevators is in some respect quite unlike interior elevators. Whereas most of the grain stored in the interior terminal elevators is usually for the account of the owner, the grain brought into a port elevator is mainly for the account of exporting firms, and the operator of the elevator seldom is the owner of the grain handled. The main function of a port elevator is to elevate grain from cars, trucks, or barges into the elevator for storage only until ready to be loaded into vessels. Since these elevators are really not meant for storage, utilization of these facilities will be defined as a ratio of the volume of shipments each quarter to storage capacity. A low ratio suggest a slow turnover in inventories and the existence of excess capacity.

The utilization of port facilities for the marketing year under consideration is shown in Table LVI. The highest ratio of shipments to capacity existed in region 50 (this region included facilities in Alabama, Mississippi, and Louisiana) where shipments were 27 times storage capacity. The two smallest ports in terms of capacity (North Charleston and Long Beach) had ratios in excess of 12. The lowest utilization ratio occurred in the Stockton region where the quarterly ratio was never greater than 0.4. No attempt will be made here to define what ratio a particular port should have to be efficiently utilized. However, these data suggest that excess capacity exists in several port regions.

Comparative Cost Analysis

The time-staged model resulted in a total cost of $1,511 million with domestic transportation, export transportation and storage accounting for $756, $411, and $345 million, respectively. When the associated costs of milling and flour distribution as determined in Model I are added, the total marketing bill comes to $1,744 million.

TABLE LVI

UTILIZATION OF PORT TERMINAL FACILITIES: STORAGE CAPACITY, VOLUME SHIPPED, AND RATIO OF SHIPMENTS TO STORAGE CAPACITY BY QUARTER, JULY 1966–JUNE 1967

	Port Region	Storage Capacity	Volume Shipped				Ratio of Shipments to Storage Capacity				
			Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Annual
			10,000 Bu.								
43	Superior	5,203	4,271	4,476	0	2,797	0.82	0.86	0.00	0.54	2.22
44	Chicago	5,822	3,136	3,012	0	1,521	0.54	0.52	0.00	0.26	1.43
45	Toledo	1,909	739	3,225	0	1,954	0.39	1.69	0.00	1.02	3.10
46	Albany	1,382	714	235	544	165	0.52	0.17	0.39	0.12	1.20
47	Baltimore	1,746	1,972	2,761	2,932	601	1.13	1.58	1.68	0.34	4.73
48	Norfolk	711	1,077	1,489	1,711	1,057	1.51	2.09	2.41	1.49	7.50
49	N. Charleston	64	95	303	402	278	1.48	4.73	6.28	4.34	16.84
50	New Orleans	2,487	14,995	19,526	18,760	15,147	6.03	7.85	7.54	6.09	27.51
51	Houston	4,544	13,239	11,469	7,942	7,571	2.91	2.52	1.75	1.67	8.85
52	Long Beach	327	871	1,340	1,238	777	2.66	4.10	3.78	2.38	12.92
53	Stockton	1,085	120	314	391	128	0.11	0.29	0.36	0.12	0.88
54	Portland	2,855	3,205	4,697	4,313	4,492	1.12	1.65	1.51	1.57	5.85
55	Seattle	1,271	1,213	867	664	1,177	0.95	0.68	0.52	0.93	3.08

The grain accounting for the largest portion of the total was feed grain, with expenditures for transportation totaling about $729 million. Storage charges for feed grain were $191 million (Table LVII) and accounted for over 55 percent of the total charges for storage.

The costs incurred for storage and transportation for the time-staged model are presented in Table LVII. The most significant changes in transportation costs were associated with hard wheat. Domestic hard wheat transportation was about $21 million higher in the quarterly analysis, while transportation cost for moving hard wheat to ports decreased about $3 million. A large portion of this cost increase was associated with the transhipment of large quantities of wheat from North Dakota and Montana to Minnesota at harvest time for storage and subsequent shipment rather than moving directly to demand points as was the case in Model I. Such shipments were necessary because of inadequate storage capacity in Montana and North Dakota. Some of this grain moved to ports in later quarters from southern Minnesota, so to the extent that this happened, export transportation was under estimated and domestic transportation was over estimated by the same amount. Quantities transhipped into a region were not distinguished from local supplies in this study; therefore, it was impossible to allocate the cost of such movements between domestic and export. In aggregate, the transportation cost increase associated with bringing into play the storage capacity constraints through a quarterly, time-staged model was about $23 million.

TABLE LVII

SELECTED COSTS OF MARKETING GRAIN, TIME-STAGED MODEL

Type of Grain	Storage Cost	Transportation Cost Domestic	Transportation Cost Export
	Thousand Dollars		
Hard Wheat	77,285	101,078	146,105
Soft Wheat	23,933	23,456	40,024
Durum Wheat	7,889	14,396	6,483
Feed Grain	190,783	588,591	170,110
Soybeans	44,831	58,827	47,855
Total	344,721	756,348	410,577

FOOTNOTES

[1]James L. Driscoll and James E. Martin, Structural Changes in the Oklahoma and Texas Grain Marketing Industries, Oklahoma Agricultural Experiment Station Processed Series P-571 (Stillwater, August, 1967), pp. 4-5.

[2]Walter G. Heid, Jr., James E. Martin, and Russell F. McDonald, Changing Structure and Performance of the Northeast Grain Marketing Industry 1957-1962, Maryland Agricultural Experiment Station Misc. Pub. 545 (College Park, June, 1965), p. 36.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The geographic distributions of production and consumption of the major food and feed grains in the United States are quite different, and very large expenditures are incurred by firms and agencies in the grain marketing system in moving the grain from production areas to consumption areas. The cost of transportation represents a very large portion of the marketing bill for grain, and sub-optimal shipment patterns can greatly increase the total cost of marketing grain. Thus, knowledge concerning the optimum interregional flows is of prime importance to decision makers associated with grain marketing, and determining these flow patterns was an objective of this study.

A very important industry involved in grain marketing is the grain handling and storage industry. Its importance is derived from the seasonal nature of grain production, and the industry performs the function of matching supplies and demands over the marketing year as well as from year to year. The annual supply of all the major grains in the United States has been greater than domestic and export requirements for many years and the storage industry has been storing the carryover. Reductions in the carryover of food and feed grains during the 1960's have resulted in excess storage capacity in many regions of the United States. The total carryover of wheat and feed grain declined from 4.6 to 2.2 billion bushels between 1961 and 1966. Hence, there is a need to evaluate regional storage needs and determine the regions in which excess capacity is a serious problem.

The transportation rate structure (the relationships between the rates for grain and those for grain products) have undergone significant changes in recent years, and these changes have necessitated adjustments in the optimum flow patterns. In addition, these structural changes in rates have important implications for plant location in the flour milling industry. Thus, there is a need to specify least-cost flow patterns consistent with an optimum utilization of existing milling capacity and to evaluate the benefits of plant relocation in an effort to reduce total marketing cost.

Theory relating the transportation rate structure and the location of economic activity was discussed. The "fixed market" approach and the "market area" approach were considered. The works of von Thunen and Weber were discussed in relation to the fixed market approach. They addressed the problem of determining the location of economic activity assuming the markets are fixed. The contributions of Fetter and Losch to market area theory were considered. This branch of the theory deals with the problem of determining where existing firms should market their product assuming a given (existing) locational pattern. The implications of the transit rate system for grain and grain products on the location of flour milling was discussed, also.

Given the problems related to the utilization of storage and milling facilities, a multi-product transhipment model encompassing these industries was formulated. The model was designed to determine simultaneously the optimum flows of hard wheat, soft wheat, hard-wheat flour, soft-wheat flour, durum wheat, feed grain and soybeans that would minimize the total combined cost of handling, storage, milling and transportation for the grain marketing system. Solution of this model also determined the optimum utilization of milling and storage capacity as well as the equilibrium interregional price differentials based on existing transportation rates. The model was then extended to include multiple time periods. Such a model is particularly useful in studying problems that involve seasonality in production and/or consumption.

Given the formal model, the continental United States was delineated into 42 domestic regions. In addition, 13 port regions were specified as ports of exit for grain and flour exported from the United States. Given the regional demarcation, regional data related to supplies, demands and capacities of storage and processing were estimated. Data were also obtained on the costs of handling, transporting and storing grain and milling flour. Given the basic data and the operational model, three annual analyses were made with primary emphasis on interregional flows and utilization of milling capacity. Since grain production is seasonal, an annual model largely ignores the peak demands for storage capacity; therefore, these analyses were followed with a quarterly analysis to study the seasonal utilization of regional storage capacity and the associated quarterly flow patterns.

The annual analysis of Model I simultaneously determined the least-cost flow patterns for the five grains and two types of flour, the optimum level of regional milling activities, and the intermarket equilibrium price differentials for each grain and flour. From the standpoint of the flour milling industry, this analysis would be considered a market area approach in that the location of milling capacity was taken as given, and the markets that should have been served by each milling region to minimize total marketing cost were determined. In Model I, regional flour milling capacity was restricted to the actual capacity in existence during 1967 for an operating year of 254 days, and the supply and demand conditions of the 1966-67 marketing year were assumed. The marketing bill was about $1,377 million excluding charges for grain storage. The costs of domestic transportation, export transportation, and flour milling were about $797, $425, and $155 million, respectively.

The assumed conditions of Model II were the same as in Model I except that milling capacity was not restricted to the regional distribution that existed during 1967. Milling activities were allowed to shift to locations that would have minimized total cost to the marketing system given the existing transportation rate structure and regional costs. This Model was designed to determine the optimal location of flour milling given the 1967 regional flour requirements, and would be considered an application of the fixed market approach of Weber. In general, hard-wheat milling activities shifted to a market orientation with some notable exceptions, and the total marketing bill excluding storage was reduced almost one percent or about $11.3 million. This is the amount that marketing costs would have been reduced if the regional location of the milling industry had been optimally adjusted to the transportation rate structure.

The annual analysis of Model III was designed to study the effects on the optimum supply sources for the various consumption regions if minimum working inventories were maintained at all grain destinations.

The assumed conditions were the same as in Model I except that each domestic grain consumption region or destination point was required to maintain reserve inventories equivalent to 15 percent of the annual requirements for wheat and feed grain. In addition, working inventories at ports were specified as 5 percent of the volume of wheat and feed grain exported during 1966-67. These restrictions had the effect of increasing the demand in consumption regions and introduced a new source of competition for available supplies. Consequently, many regions were forced to draw shipments of grain from more distant origins to satisfy their requirements, and total marketing cost increased almost 13 percent. The cost of handling and transporting grain to domestic and export destinations increased by $132 and $40 million, respectively. Feed grain accounted for 81 percent of the increase in domestic handling and transportation and 71 percent of the increase associated with export movements.

The fourth analysis was a time-staged quarterly analysis for the 1966-67 marketing year. Regional supplies and demands were specified by quarters, and minimum-cost flow patterns were determined simultaneously for the four quarters. Because of computational difficulties related to the size of the model involved, flour milling activities and flour distribution patterns were assumed to be the same as those determined in Model I. Thus, the regional quantities of hard wheat and soft wheat milled in the annual analysis were introduced into the quarterly model as whole grain demands in the various milling regions. The five grains competed for the limited grain storage capacity of each region in the quarterly model, and several regions had significant amounts of storage capacity in excess of 1966-67 requirements. The most serious excess capacity problems were located in Kansas, Oklahoma, and Texas. Storage capacity constraints forced some alterations in the least cost flow patterns determined in Model I, and some transhipment activities were introduced into the solution. As a result, the total cost of handling and transportation increased by about $23 million over that of the analysis of Model I, and most of the increase was associated with hard wheat flows.

Conclusions

Implications

The results presented in the preceding chapters were obtained by formulating transhipment models of the grain marketing system and generating solutions by use of linear programming procedures. The four analyses were based on data for the 1966-67 marketing year and were not intended to be predictions of how the system will operate in the future. The results described the flows and activity levels that should have occurred during 1966-67 given the supply and demand conditions, industry location, and transportation rate structure that existed. Since data on actual interregional flows were not available, comparison of the results with actual flows was not possible. However, meaningful conclusions can be drawn concerning the results.

When the analyses of Models I and II are compared, it is evident that incentives existed for shifts in the location of flour milling, especially hard-wheat milling activities. The key element affecting the location of flour milling was the relationship between the costs of transporting wheat and of transporting flour. This relationship has undergone significant changes in recent years and today flour is more costly to ship to many destinations than wheat. As was indicated by the results, many regions east of the Mississippi River will probably experience an expansion in flour milling capacity in the future as the industry assumes more of a market orientation. Such an expansion will permit the industry to utilize low-cost water transportation to a greater extent.

The results indicate that a savings of about $13.6 million in handling and transportation costs would have resulted if the milling industry had been properly oriented to the transportation rate structure. The extent and speed in which the industry assumes the market orientation depicted in the results depend upon many factors. An important impediment to locational shifts is the condition of existing capacity that would become excess in the process. If the facilities are obsolete, the move probably would be much more rapid than if the facilities are new and/or technologically efficient. However, evidence seems to indicate that if the disadvantage at a particular location is great enough, firms will close mills regardless of condition of the facility. For example, The Pillsbury Company decided to close its plant at Enid, Oklahoma, during 1968. The plant was modern, and in 1957 air-classification process for milling and bulk flour storage facilities were installed and other improvements were made at a cost of $900,000.[1]

A very important impediment to mill relocation is uncertainty that exists regarding transportation rates. Effective transportation rates between various points are subject to change on short notice and have changed significantly in recent years. Therefore, small locational advantages may not be permanent, and decision makers in the industry may be hesitant to make investments in milling capacity unless they have some degree of optimism on rate stability.

The changes in the optimum flows resulting from the introduction of minimum inventory levels (Model III) indicate that the results of spatial models are very sensitive to the assumptions or restrictions involved in model formulation. There were several significant changes in the flow patterns for hard and soft flours and corresponding changes in the quantities milled in the various regions; however, the combined cost of milling and flour distribution was about the same for Models I and III. These costs were only $400,000 lower in Model III, a decrease of less than two-tenths of one percent. This fact suggests that many alternative flow patterns exist which will not have a significant effect on total cost to the system.

When the results of the quarterly analysis are compared with those of Model I it is evident that regional storage capacity restrictions are an important consideration. Annual models largely ignore these restrictions and understate the additional handling and transportation costs associated with grain transhipments from production regions to storage regions. Insufficient storage capacity in Montana and North Dakota resulted in sizable transhipments of wheat to Minnesota for storage prior to shipment to the various consumption regions. The shipping and receiving cost incurred by these shipments amounted to about $4 million.

Results of the quarterly model also indicate the quarter in which shipments should take place so that the available storage capacity may be more efficiently utilized. For example, the annual analysis indicated that Ohio should ship large quantities of feed grain to the deficit Northeast. The quarterly model indicated this, but it also showed that the volume shipped to the Northeast should be greater in the first two quarters since Ohio's storage capacity was completely filled at the end of the fall quarter. At the same time, a large portion of the feed grain produced in the Northeast was stored until the last two quarters. Information related to timeliness of shipments is very important if the marketing system is to function efficiently.

The time-staged model proved to be quite useful in studying the utilization of inland storage capacity and pinpointing regions in which storage capacity was excessive. Eleven regions had a utilization percentage less than 75 in the peak quarter. The most serious excess capacity problems existed in Kansas, Oklahoma, and Texas. If the annual carryover of grain is kept down to a reasonable level in the future, the burden of adjusting storage capacity to more desirable levels will be most keenly felt in these regions. Such adjustments will probably come about slowly since fixed costs represent a large proportion of the total cost of operating an elevator, and variable costs can be covered with a low volume.

The dual variables of linear programming provided a set of price differentials at the origins and destinations consistent with the demand and supply specifications for 1966-67. These price differentials could be used as a basis for setting the geographic loan rate surface by policy officials. On the basis of these estimated price surfaces, loan rates could be raised or lowered in certain regions to accomplish desirable adjustments in regional production. The price differentials also provide an estimate of the comparative price advantage of one production region or market over another. The differentials at the export points provide an estimate of the cost advantage of various ports in the assembly of each grain at dockside. If ocean freight rates from the various ports are used in conjunction with this information, the least-cost port of exit for each grain to various foreign destinations can be computed. For example, the data of Table XXX indicated that Gulf ports (New Orleans and Houston) had an advantage over Seattle of 6.2 cents per bushel in exporting hard wheat. However, the weighted average ocean freight rates for heavy grain in voyage-chartered U.S.-flag vessels from Seattle to East Coast India was about 9 cents less than the rate from Houston during 1966.[2] Thus, if U.S. exporters sold hard wheat F.O.B. East Coast India, the Seattle port would be the least-cost port of exit to that destination.

The optimal solutions to the problems formulated in this study minimized total cost to the marketing system as a whole. The achievement of such a solution in reality would require that the marketing system be under the direction of a single decision making unit because minimizing cost to the system does not imply that cost for each individual segment of the system was minimized. In addition, there were many instances where the requirements at a particular grain destination were not satisfied with shipments from origins of least transportation cost. An example of this was discussed in which Oklahoma's feed grain requirements were satisfied with shipments from Kansas, and that was just one of many examples that could have been cited. This is analogous to a firm that owns many plants. An operating plan which maximizes the profits of each plant will not usually maximize firm profits and vice versa.

Another very important consideration in interpreting results of specific transportation problems is that the attainment of an optimum solution does not usually imply that the solution is unique. In most cases several alternative solutions exist, and the frequency of multiple solutions generally increases as the number of stages under consideration increase. In addition, consideration of several periods of time simultaneously (time-staging) greatly increases the number of alternatives. Although the alternative solutions yield the same total cost to the system, the total cost for a particular segment, region or industry may be different under each solution. Since alternative solutions existed, some discrepancy between flow patterns presented and what actually happened in the real world is possible without adversely affecting total marketing cost.

Limitations

Although the model employed and results of the four analyses have provided insights into needed adjustments in grain storage and flour milling industries and the competitive position of various regions in grain marketing, there were some notable limitations that should be pointed out.

First, feed grain was treated as a homogeneous commodity in this study. In reality, most of the uses other than feeding require a particular grain, and other feed grains cannot be substituted. However, the four major feed grains may be substituted, within limits, for each other in livestock feeding, and, since this was by far the most important use, these grains were grouped together as a single commodity.

Second, the decision to incorporate a uniform storage charge into the model rather than some sort of regional estimates of storage costs probably affected the timeliness of some quarterly shipments. It is not very likely that aggregated annual flows between the various regions would have been affected, but inventories in regions having a higher cost might have been depleted first if cost estimates were incorporated. For example, if the cost of storage were higher in New York than in Indiana, the feed grain produced in New York would probably have been consumed in the winter quarter rather than the spring, and shipments from Indiana to New York would have been correspondingly reduced in the winter and increased in the spring.

Third, millfeed, a byproduct of flour milling, was not considered in this study. Millfeed represents about 10 percent of the value of the output of a flour mill and 28 percent of the volume. This relatively low valued, bulky product is used by the mixed feeds industry. Since the geographical location of the mixed feed industry is not the same as flour consumption centers, the decision to locate a flour mill must take into account the transportation cost involved in marketing both joint products of flour milling.

Fourth, the assumption that the most economical mode of transportation would own sufficient transport equipment to perform the necessary transportation may be violated in reality. In many regions there are shortages of equipment around harvest time, and this could alter the timeliness of flows depicted in the model.

Need for Further Study

The transhipment model formulated for this study was the first attempt to incorporate storage, processing, and multiple time periods into a spatial model related to grain marketing. The model as formulated has several limitations and needs refinement in many areas. An expansion of the model to include grain production activities, regional production costs and cropland restraints, while relaxing the assumption concerning fixed supplies, could provide valuable information concerning the comparative advantages of various production regions. Such an approach would integrate the production and marketing aspects into a single model and should prove quite valuable to policy makers. It would be desirable in such models to consider a smaller number of time periods (say two six-month periods) and consider several alternative situations or sets of assumed conditions. This approach would provide more information per dollar spent on data processing.

Additional research is needed which incorporates actual costs of providing transportation service into the model rather than the current transportation rate structure. Transportation rate data probably present the greatest difficulty to the researcher in spatial equilibrium research. The use of the current transportation rate structure undoubtedly introduces error into the estimates of optimum spatial flow. Transportation rates appear to be gravitating toward a cost of service basis; therefore, a study incorporating rates based on costs of providing transport service would provide better results for long-run models projecting shifts in locational patterns.

A model such as the one formulated could be very useful in predicting the effects on geographical flows and price differentials of alterations in the transport rate structure as well as changes in geographical supplies and demands.

Many problems of the spatial equilibrium type lend themselves to the time-staged transhipment model. Formulations similar to the one employed should be feasible for many agricultural commodities or commodity groups. An optimal solution for a problem describing the activities of an industry (or industries) involved in marketing a particular product(s) could be useful to firms entering the industry or system in suggesting which markets should be investigated or where facilities should be located.

FOOTNOTES

[1] "Severe Economic Problems at Enid Mill," The Southwestern Miller, Vol. 47, No. 19 (Kansas City, July 9, 1968), pp. 27, 39.

[2] U. S. Department of Agriculture, Heavy Grain Exports in Voyage-Chartered Ships, Rates and Volume, Economic Research Service, Marketing Research Report No. 812 (Washington, January, 1968), pp. 33-34.

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APPENDIX

INDUSTRY DATA

TABLE LVIII

DRY CORN MILLING INDUSTRY: PLANT NUMBERS AND DAILY CAPACITY BY STATE, UNITED STATES, 1965

Region and State	Reporting Plants		Other Plants[a]		Total Capacity
	Number	Capacity	Number	Capacity	
		cwt.		cwt.	
MIDDLE ATLANTIC					
New York	1	100	0	0	100
Pennsylvania	6	2,305	0	0	2,305
SOUTH ATLANTIC					
Deleware	2	210	0	0	210
Maryland	1	100	0	0	100
Dist. of Col.	1	500	0	0	500
West Virginia	1	2,000	1	317	2,317
Virginia	19	3,802	0	0	3,802
North Carolina	21	6,315	0	0	6,315
South Carolina	5	1,520	0	0	1,520
Georgia	8	3,090	0	0	3,090
Florida	1	1,150	0	0	1,150
NORTH CENTRAL					
Ohio	3	720	0	0	720
Indiana	5	2,250	2	1,826	4,076
Illinois (N)	0	0	3	2,739	2,739
Illinois (S)	2	500	2	1,826	2,326
Wisconsin	0	0	1	913	913
Iowa (S)	1	3,600	0	0	3,600
Missouri	1	4,800	2	1,826	6,626
Nebraska	1	1,200	1	913	2,113
Kansas (S)	2	620	0	0	620
SOUTH CENTRAL					
Kentucky	16	7,150	1	608	7,758
Tennessee	24	15,274	1	608	15,882
Alabama	2	1,900	1	608	2,508
Mississippi	1	50	1	608	658
Oklahoma	2	3,000	0	0	3,000
Texas (W)	1	100	0	0	100
Texas (S)	2	2,650	0	0	2,650
Texas (E)	3	2,100	1	608	2,708
PACIFIC					
Washington	1	336	0	0	336
California	1	120	1	228	348
UNITED STATES	134	67,462	18	13,628	81,090

[a]Plants not reporting capacity were assigned a capacity equivalent to the average capacity of reporting plants in the region.

Source: The Northwestern Miller, (September, 1965), pp. 68-80.

TABLE LIX

WET CORN MILLING INDUSTRY: GEOGRAPHIC DISTRIBUTION OF PLANTS BY SIZE, UNITED STATES, 1963

Region and State	Number of Plants	Number of Plants with Employment of 1-19	20-49	50-99	100-249	250-499	500-999	1000 or more
NEW ENGLAND								
Maine	16	14	2					
Massachusetts	2	1	1					
MIDDLE ATLANTIC								
New York	1	1						
New Jersey	1	1						
Pennsylvania	2	1	1					
SOUTH ATLANTIC								
Maryland	1		1					
Georgia	1	1						
Florida	1	1						
NORTH CENTRAL								
Ohio	5	4		1				
Indiana	2					1		1
Illinois (N)	3	1						2
Illinois (S)	2						1	1
Iowa (S)	3						2	1
Missouri	2				1		1	
North Dakota	1	1						
SOUTH CENTRAL								
Texas (S)	1					1		
Texas (E)	2	2						
MOUNTAIN								
Colorado	3	3						
Idaho	6	5			1			
PACIFIC								
California	4	3			1			
Washington	1	1						
UNITED STATES	60	40	5	1	3	2	4	5

Source: Location of Manufacturing Plants by Industry, County and Employment Size, Part 1, Bureau of the Census, 1963, pp. 75-76.

TABLE LX

BARLEY MALTING INDUSTRY: GEOGRAPHIC DISTRIBUTION OF PLANTS BY SIZE, UNITED STATES, 1963

Region and State	Number of Plants	Number of Plants with Employment of						
		1-19	20-49	50-99	100-249	250-499	500-999	1000 or more
MIDDLE ATLANTIC								
New York	5	2	3					
New Jersey	1	1						
NORTH CENTRAL								
Ohio	1	1						
Illinois (N)	5		1	3	1			
Michigan	1			1				
Wisconsin	15	4	6	2	3			
Minnesota (S)	10	3	4	3				
Missouri	1		1					
PACIFIC								
Washington	1			1				
California	2		1	1				
UNITED STATES	42	11	16	11	4			

Source: Location of Manufacturing Plants by Industry, County and Employment Size, Part 1, Bureau of the Census, 1963, p. 94.

TABLE LXI

CEREAL MANUFACTURING INDUSTRY: GEOGRAPHIC DISTRIBUTION OF PLANTS BY SIZE, UNITED STATES, 1963

Region and State	Number of Plants	Number of Plants with Employment of						
		1-19	20-49	50-99	100-249	250-499	500-999	1000 or more
NEW ENGLAND								
Vermont	1		1					
Massachusetts	1				1			
MIDDLE ATLANTIC								
New York	4		1	1		1	1	
New Jersey	1			1				
Pennsylvania	3	1		1	1			
SOUTH ATLANTIC								
North Carolina	1	1						
Georgia	1	1						
NORTH CENTRAL								
Ohio	3	2	1					
Indiana	2		1			1		
Illinois (N)	3	2					1	
Michigan	5		1	1		1		2
Minnesota (S)	3		2		1			
Iowa (S)	2					1	1	
Missouri	1	1						
Nebraska	2		1			1		
Kansas (N)	1	1						
Kansas (S)	1	1						
SOUTH CENTRAL								
Tennessee	1						1	
Oklahoma	1		1					
Texas (E)	1	1						
MOUNTAIN								
Montana (E)	2	2						
PACIFIC								
Oregon	1	1						
California	7	4	1	1		1		
UNITED STATES	48	18	10	5	3	6	4	2

Source: Location of Manufacturing Plants by Industry, County and Employment Size, Part 1, Bureau of the Census, 1963, pp. 72-73.

VITA

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