ECONOMIC ANALYSIS OF CATTLE AND BEEF TRANSPORTATION RATES FOR ENERGY CONSERVATION POTENTIAL

by

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CHAPTER I

INTRODUCTION

The transportation of agricultural products is exempt from Interstate Commerce Commission (ICC) regulations when moved interstate. However, various state regulatory commissions and boards have the power to establish intrastate transportation rates in several states. United States Department of Agriculture studies have indicated that the costs of regulated carriers are 10 to 30 percent higher than exempt carriers (10, p. 118). Such wide differences in transportation costs due to differences in the existing interstate and intrastate regulations have often caused the transportation costs for agricultural products to be greater for shorter distances than for longer ones.

Regulation of the transportation system in a manner that requires traveling greater distances to achieve least-cost routes results in an inefficient use of petroleum fuels. This occurs in a period when the nation can ill-afford to waste petroleum. Excessive resource use has become a major concern in recent years due to large increases in the price of domestic and foreign crude oil. However, voluntary cooperation by the general public in reducing energy consumption has been slow in coming, even in the face of rising petroleum prices. The nation has become more and more dependent upon petroleum imported from abroad.

Transportation of agricultural products represents a major use of petroleum fuels in the United States. This transportation makes up a major portion of the marketing costs of agricultural products, because most agricultural production takes place in rural America while most consumption takes place in widely separated urban centers. Another fact adding to the costs of shipping, thus marketing costs, is that most agricultural products are bulky in nature. Transportation costs for agricultural products for 1976 were estimated at 8 billion dollars (34, p. 47). Since (1) transportation is important to the agricultural sector and to the nation as a whole, and (2) energy conservation is an important national issue, more efficient petroleum use in the shipping of agricultural products must be considered.

A major problem with the ICC regulations applicable to agricultural products is that the efficient allocation of transportation resources has never been an important aspect of the regulatory rate structure. The use of value-of-service pricing instead of establishing rates reflective of actual shipping costs has diverted traffic from railroads to the relatively more expensive trucking industry. At the time the regulations were established, abundant energy supplies were taken for granted. Cross-hauls and back-hauls were not problems. However, at the present petroleum energy supplies are more restricted and fuel costs are much higher. Cross-hauls and back-hauls burn fuel which could be used more efficiently if the regulatory rate structure were revised.

Revising the regulatory rate structure to reflect shipping costs instead of value-of-service pricing would be a move away from subsidizing the agricultural sector. Value-of-service pricing costs the agricultural sector and the entire nation considerable amounts of petroleum fuel. More efficient fuel use could lead to lower transportation costs and lower marketing costs. Therefore, it is essential to reconsider rate policies in order to reduce or eliminate inefficiencies.

Objectives

The major objective of this study is to examine the existing rate structure for the transporting of cattle and beef by truck within the continental United States to determine possible petroleum savings for the nation.

More specifically, the objectives are to:

(1) Determine the optimal flow of cattle and beef between production centers and consumption centers throughout the various stages of production which minimizes the total cost of transportation under the existing rate structures;

(2) Determine the optimal flow of cattle and beef between production and consumption centers which minimizes the total energy consumption requirement;

(3) Determine the difference in energy requirements between the two optimal flows of cattle and beef-total cost minimization vs. total energy consumption minimization; and

(4) Draw policy implications for future regulation of the flow of livestock and meat.

General Procedures

To satisfy the stated objectives, this study used computer programming to generate results as to least-cost routes and fuel consumption for present and unregulated rate structures. The basic computer model employed is the Mathematical Programming System for IBM's 360 computer as adapted by Richard K. Perrin (27).

The program used is a normative model referred to as the "transportation model." This model deals with the selection of shipping routes in a manner that minimizes the cost of transporting a uniform commodity from a specified origin to a specified destination. Normative models are not designed to necessarily "fit" actual flow patterns, but are used to determine what the flows should be if transportation costs are to be minimized (11, p. 157).

Certain information is required to utilize the transportation model. This information consists of:

(1) location of all origins and destinations,

(2) distances between all origins and destinations,

(3) amount to be shipped from each origin,

(4) amount to be received by each destination,

(5) cost per unit of shipping from any origin to any destination.

This information, along with other information necessary for the study, was collected on a county basis where possible, and on a crop-reporting district basis elsewhere. Constraints upon the transportation model were that origins could not ship more than they had to ship, and destinations could not receive more than they actually received (11, p. 160).

After optimal least-cost flow patterns were established for the present regulatory system and under an unregulated system in which all rates are a function of distance, potential differences in fuel consumption between the two rate structures were derived. Policy implications were, then, drawn regarding transportation regulations and energy conservation.

History of Regulatory Rate Structure

The ICC presently controls rates, entry, and service of intrastate rail, water, and motor carriers. This regulatory control represents a 90-year history in which every major piece of transportation legislation since 1887 has increased the authority of the ICC (26, p. 244). The resulting complexity of the regulatory structure has brought about regulations that are often inconsistent and overlapping; a person or firm is subject to many different regulations by many different agencies at the same time.

The Interstate Commerce Act of 1877 created the ICC to control exploitation by the railroad companies of their economic power. The railroad companies were employing price discrimination among shippers, localities, and goods. The results were higher prices for small-lot shippers with no countervailing power, higher rates to isolated areas that had no alternative mode of transportation, and higher rates for high-value goods. The 1887 Act called for just and reasonable rates and prohibited price discrimination on the basis of preference between people, localities, and distances traveled (i.e., charging more for shorter hauls). While this law also banned the practice of "pooling" or cartelizing the railroad industry, it defended the practice of value-of-service pricing by the industry (10, pp. 8-13). The reasoning underlying this legislation and other regulations will be discussed more completely in the next section.

The next major legislation which added to the authority of the ICC was the Motor Carrier Act of 1935. This act placed interstate motor carriers under the jurisdiction of the ICC. It also covers purely intrastate carriers who transport commodities moved interstate. Some of the exemptions to the Act are motor carriers used exclusively in the carrying of livestock, fish, and agricultural products, not to include manufactured products thereof. The exempted list was expanded in 1952 to include horticultural products (22, pp. 676-677).

The main reason for the Motor Carrier Act of 1935 was the amount of competition which existed in the motor carrier industry in the late 1920's and early 1930's. The intensive competition found in the industry prior to the Act was believed to have brought about losses for trucking firms as well as a substantial diversion of traffic from the railroads. As a result, the 1935 Act was designed to restore order to the motor carrier industry by restricting competition through maximum and minimum rate controls, entry and exit controls, and safety and financial controls (8, pp. 103-104).

In addition to the ICC regulations mentioned above, almost every state has one or more agencies, usually regulatory commissions or boards, for the economic regulation of intrastate transportation (3, p. 45). The authority of these state agencies is limited to intrastate transportation only, and there are wide variations in intrastate regulations between the various states. Concerning agricultural products, over 78 percent of the states require operating authority over agricultural carriers, 56 percent regulate routes, 62 percent regulate rates, and 70 percent have insurance requirements (21).

Reasons for ICC Regulations

Farris has written that regulation of the transportation sector in the U.S. has been used both to protect the public from monopolistic practices, as in the Interstate Commerce Act, and from excessive competition, as in the Motor Carrier Act (9, pp. 94-98). Another reason for regulation, as suggested by Nelson and Grenier, is to promote the welfare of certain sectors of the economy (25, pp. 372-373).

The latter reason concerns the practice of maintaining rate differentials between low-value commodities and high-value commodities through value-of-service pricing. By charging more for high-value goods, this policy acts as an income transfer program by taxing producers and consumers of high-value goods while subsidizing low-value bulk commodities such as agricultural products. Friedlander has written that this policy was used in the early days of regulation when low rates on bulk commodities and high rates on manufactured goods acted as a subsidy to the early Western farmer and mining interest and as an income transference from the manufacturing sector to the agricultural sector to encourage the settling of the West. However, the ICC has continued to stress the need to consider the depressed state of the agricultural sector (10, p. 127). The effect of such a redistribution of income has undoubtedly been enormous, but it is felt to be immeasurable (25, pp. 372-373).

Criticisms of ICC Regulations

It is important to note at this point that it has been stated that at no time has the ICC assumed any responsibility to plan or arrange an optimum rate structure in conformity to any principle, such as the most efficient allocation of transportation resources (7, p. 22). This was not a very important point when the ICC was first established and abundant energy supplies were taken for granted. Today, however, the conservation of petroleum energy has become an important consideration and must become a major factor in the regulatory rate structure governing the transportation of agricultural products.

Considerable literature has addressed the possible misallocation of resources due to the existing rate structure established by the ICC. The basic argument is that by allowing value-of-service pricing and not permitting rates to be more reflective of relative shipping costs, goods fail to travel on the least-cost carrier and the ICC, thus, generates a misallocation of resources (10, p. 65; 24, p. 274). As stated in Friedlander's book, Meyer has determined that trucks have a clear cost advantage for traffic less than 100 miles; railroads have a narrow cost advantage at 100 miles; and railroads have a clear and increasing cost advantage for traffic traveling over 200 miles. Since 91 percent of all truck traffic is greater than 200 miles, the implication is that value-of-service pricing policies make it profitable for trucks to carry products that could be shipped cheaper by rail (10, p. 66).

Even though railroads are best suited to carry high-density commodities, employing the policy of charging higher rates for higher-value goods had effectively diverted traffic from railroads to the trucking industry. Nelson has written that this diversion of high-value commodities from low-cost railroads to higher-cost trucks has led to a misallocation of traffic and resources worth several billions of dollars each year (24, p. 274). If shipping rates were more reflective of transporting costs, railroads would perform more of a wholesaling service, specializing in high-density traffic between major centers. Trucks would perform a retailing or distribution service, specializing in the handling of low-density commodities. This type of specialization would result in a diversion of large-volume trucking traffic to rails, a diversion of low-volume rail traffic to trucks, and lower costs of transporting (10, p. 69).

Various writers have brought up other criticisms of ICC regulations. The misallocation of traffic and resources mentioned above contributes to the ever-increasing problem of inflation (6, pp. 5-6). A once highly competitive trucking industry has been cartelized by the regulatory system, and trucking firms have grown beyond economies of scale under restrictive entry controls (24, p. 274). The system has encouraged costly service competition, erosion of position of common carriers and nonregulated and exempt carriers, widespread excess capacity, and a lack of technological change in the transportation sector (24, p. 274; 10, p. 1). The ICC cost data upon which rates are based is subject to considerable error and bias (10, p. 32). There is (1) excessive adherence to court procedure by the ICC, (2) a lack of responsiveness to general political and economic trends, (3) an identification with the industries regulated, and (4) a failure to give a realistic and broad base to policy because of case-by-case procedures (7, pp. 20-21).

According to Nelson, the present regulatory system has produced both widespread dissatisfaction in the system and an increasing desire for deregulation and to allow competition to work (24, p. 274). Peck asserts that a competitive policy in transportation is possible and desirable. He suggests employment of a new system based upon "simple and objective" information like distance and cost of handling particular goods (26, p. 271).

A final criticism concerns the interaction of state regulatory commissions and boards with the ICC. As stated above, the state agencies have the power to establish intrastate transportation rates. The wide difference in intrastate regulatory rates between the states has resulted in a system that is highly complex, often inconsistent, and overlapping. Firms and individuals are subject to many regulations by different agencies at different levels (3, p. 47). Whitten estimated the total number of possible freight rates in the United States at 1,440,000 quintillion (39).

Production Stages and Distances Between Stages

As mentioned at the beginning of the previous section, petroleum fuel conservation must become a major consideration in the regulatory rate structure governing the transportation of agricultural products. The potential for improving resource allocation and efficiency in the transportation of agricultural products should be significant. However, due to the number of agricultural products involved, the many different modes of transportation used, and number and variety of agencies regulating rates, among other reasons, this research has been limited to the shipment of cattle and beef, transported principally by truck. It should be reasonably simple to apply the same type of analysis developed in this study to other agricultural products.

The transportation of cattle is more complex than for most other agricultural products. Cattle are shipped several times before they reach the final consumer as beef.

About 75 to 85 percent of all cattle and calves require three separate movements before they reach consumers; cattle and calves are sent from farms and ranches to feedlots, then on to slaughter houses from which they are shipped to consumption centers. Ten to 15 percent of cattle and calves are sent from farms and ranches to pasture. Most of these cattle are then shipped to slaughter, but some are sent to packing houses through the feedlot process. A small percentage of cattle, consisting mainly of culled bulls and breeding cows, are sent directly from farms and ranches to slaughter houses.

Transport costs of agricultural products represent a significant part of the cost of marketing the products. A major factor of transport costs is distance traveled between the different stages of production. Shipping movements of cattle and calves involve a considerable amount of travel due to the locations of the facilities for different production stages.

Feedlot fattening of cattle for slaughter requires large quantities of feed grains (i.e., corn, oats, sorghum, and barley). As a result, feedlot operations are limited to those areas which have adequate supplies of the required grain. But there is a problem, in that areas with adequate supplies of feed grains do not necessarily coincide with areas that produce cattle and calves. One example of this type of problem is the Southeastern part of the U.S., which is a major cattle producing region. Since the region produces only a limited quantity of feed grains, feeder cattle produced in the Southeast are shipped to other regions with more abundant grain production.

To further complicate the matter, slaughter-packing houses are not consistently located near feedlots. Traditionally, packing operations have been located near consumption centers, even though the trend is toward larger size packing houses located near cattle feeding centers. Since there may be considerable distance between production centers, feedlots, slaughter-packing houses, and consumer markets, there is an enormous volume of transportation involved in the production, feeding, packing, and final sale of cattle. Each stage of this transportation may be subject to both interstate and intrastate regulations. Since the various interstate and intrastate regulatory rates do not necessarily consider the efficiency of petroleum energy use, the least-cost shipping routes between different stages of production may not represent the shortest available distance. It is very common for products to be transported to feedlots, packing houses, or consumption centers that are not the closest ones available. The resulting implication is that there is considerable misallocation of fuel and energy in transporting livestock and meat due to existing rate regulations.

Inefficiencies in shipping agricultural products discussed above are all too common and could be avoided. It is becoming more important to identify all possible avenues of conservation and more efficient utilization of petroleum energy since society is placing a higher premium on conservation and efficient use of energy. One possibility of considerable magnitude in improved use of energy could be found in the area of shipping agricultural products.

CHAPTER II

REVIEW OF LITERATURE

The transportation model is generally considered in conjunction with linear programming. However, according to Dorfman, Samuelson, and Solow, the "transportation problem" was originated and solved by Hitchcock before the general concept of linear programming was developed. Dantzig developed linear programming in 1947 as a technique for planning the diversified activities of the U.S. Air Force. The technique was designed to consider a number of interconnected partial production functions, one for each type of activity in the organization (5, p. 106).

Hitchcock gave a mathematical solution to the problem of homogeneous product distribution, with minimization of transportation costs as the desired goal. The problem was solved through the use of geometrical interpretation as an analytical aid in finding the "best vertex" (13). Koopmans (20) gave a mathematical explanation on the use of the simplex method and linear programming to provide solutions to the problem of minimization of transportation costs. He also stated that discrepancies between actual shipping and "efficient" rates are often present in transportation systems subject to government operation or regulation. These discrepancies are a result of the

> . . . simple and crude notions of 'fairness' which have historically dominated such activity under the watching eyes of highly interested local and functional groups of population and industry.
> (20, p. 257)

The result is inefficiency in geographical distribution.

Heady and Candler explained, in a general manner, the use of linear programming to allocate the surplus product of producing areas to other deficit areas in a feasible solution (12). A feasible solution is one that will not violate the following restrictions:

(a) a surplus region cannot ship more than its total production; and

(b) a consuming region cannot import more than its total consumption (12, p. 335).

Important assumptions for the transportation model, as given by Heady and Candler, are:

(1) resources and products are homogeneous;

(2) quantities of resources or products available at the origins and the quantity requirements of the destinations are known, and total quantity required is equal to total quantity available;

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

(4) there is an objective to be maximized or minimized;

(5) transportation and conversion can be carried on only at non-negative levels (12, pp. 339-340).

The authors then showed how modifications of the transportation model can be used to provide solutions when there are inequality of quantity available and quantity required, processing problems, and procurement problems.

Dorfman, Samuelson, and Solow gave a more detailed analysis of the linear programming process as applied to a transportation problem. The authors explain that if there were, for example, M points of origin and N destinations, $M > 1$ and $N > 1$, there would be MN activities to be considered. Levels of these activities would have to satisfy M restrictions relating to origins and N restrictions relating to destinations, making a total of M+N. But if any M+N-1 restrictions are satisfied, the volume of shipments left over must be just enough to satisfy the last restriction if the solution is valid. As a result, only M+N-1 restrictions will be effective, and a minimum-cost set of routes will exist in which only M+N-1 of the activities are used at positive levels (5, p. 108).

A basic solution was then developed in which the number of routes used at positive levels was equal to the number of restraining equations. The authors then described the iterative process through which the basic solution was improved until an optimal solution was obtained (5, pp. 109-117).

Judge and Wallace conducted a three-part study in which they used a transportation model to develop a spatial price equilibrium model for the beef sector of the economy and the pork marketing system (17, 18, 19). The first part of the study was concerned with determining a set of spatial equilibrium prices of beef and the quantities consumed in each region, the quantity of beef exported and imported for each region under equilibrium conditions, the aggregate net trade and corresponding total transport cost, and the volume and direction of trade between each possible pair of regions that minimize the transport costs for beef distribution. The model was applied to 1955 data and assumed that slaughter took place at the location of production.

Other important assumptions made in this model are more extensive than in previously discussed studies, and include:

(1) objective of profit maximization for each firm;

(2) supply source and market for each geographical area are represented by fixed points;

(3) regional demands are represented by known linear demand functions, and regional supplies are predetermined for a given time period;

(4) all regions are connected by transport costs independent of the direction and volume of trade;

(5) flows of beef are unhampered by governmental or other interference;

(6) product is homogeneous, so consumers are indifferent as to source of supply;

(7) observed values of factors affecting regional consumption over and above the price of the commodity are taken as predetermined;

(8) imports and exports of beef outside the continental U.S. are negligible;

(9) for any time period, total production = total consumption of beef;

(10) both production and consumption of beef can take place in all regions;

(11) beef consumed out of local production does not require transporting since each region is represented by a point;

(12) there can be no negative shipments;

(13) there can be no cross-hauling of the product;

(14) deficit regions cannot export; and

(15) surplus regions can export only to deficit regions (17, p. 8).

An optimum solution using 21 regions was derived, and then the model was used to evaluate the effects of changes in transport costs on optimal shipments. Neither a 20 percent increase nor a 20 percent decrease in shipping costs affected the direction of flows.

The second part of the study by Judge and Wallace assumed that cattle were shipped live from the production center to the consuming center and slaughtered at the latter location. The optimal solution for 1955 annual data indicated that Texas-Oklahoma and the South would ship to the Corn Belt and the Northeast. The Mountain States and Arizona-New Mexico shipped to the West Coast. Quarterly solutions were also derived (18).

The final part of the study was similar to the first two segments; but this latter research included two models, one with 21 regions and the other with 29, to the transportation of pork and live hogs (19). Truck and rail rates for live hogs and pork were functions of the mileage traveled and its square root. The cheaper of the two modes was used for the model. The same types of functions were used for live cattle and beef in the other two segments of the project.

Maki, Liu, and Motes used a transportation model in their study of factors accounting for changing patterns of livestock production and meat consumption in the U.S. and its regions in terms of their probable effects on the location of meat packing and related industries (23). The model was applied to 1954 data to obtain optimum shipments of cattle, beef, calves, veal, hogs, and pork. However, transfer costs were used instead of just shipping costs.

According to the authors, transfer services are made up of

> . . . the gamut of activities involved in transforming the livestock into marketable meat products. Hence, differences in transfer costs occur because of regional differences in livestock procurement costs, slaughtering and processing costs, and distribution costs. Transportation expenses contribute to both procurement and distribution costs.
> (23, pp. 731-732)

The authors concluded that it would be cheaper to slaughter beef at the supply point and ship meat instead of shipping live cattle for slaughter in the consuming area (23, p. 736).

Rohdy developed a model which simultaneously furnished least-cost shipment patterns for hogs from supply areas and for pork from the slaughter areas to consumption areas (28). The costs minimized were those for slaughtering and total transportation. Data from 1960 was used, and projections were made for 1970. The procedure was based on the method of reduced matrices. Only the Southeastern states were divided into substate regions.

The generalized distribution problem which Rohdy studied is similar to a transportation problem. However, the major difference is that the generalized distribution problem considers the two transportation problem dimensions--origins and destinations--plus an infinite number of dimensions between the origins and destinations (processing, warehousing, etc.) (28, p. 28). The method of reduced matrices is much more appropriate for such a problem.

Judge, Havlicek, and Rizek conducted a three-part study of the spatial structure of the livestock economy (14, 15, 16). All three segments of the study utilized a linear programming transportation model to determine least-cost flows of livestock and meat. Data for 1955 and 1960 from 26 regions were used in the model.

The first part of the study was devoted to ascertaining the costs of transportation and optimal flow patterns of meat from slaughter to consuming areas and the relative price differentials of meat among the regions. Shipments of live animals were not considered. Meat transportation costs were estimated as a non-linear function of distance only (14, pp. 5, 18).

The second segment of the study was concerned with obtaining the regional price differentials, volume and direction of regional imports and exports of live slaughter animals consistent with total cost minimization of shipping from production to slaughter, and consequences of changes in the structure of the livestock economy (15). No consideration was given to regional slaughter capacities or the final meat consuming areas. Truck transportation rates were estimated by a regression equation in which the shipping cost was a function of highway mileage, weight of the livestock per shipment, and average speed of the haul. Rail rates were estimated as a non-linear function of rail mileage. Under the assumption that livestock is generally not moved short distances by rail, the truck and rail transport costs were combined to provide a realistic rate over all distances (15, p. 5). The main thrust of this second part was to suggest how changes in transportation costs of live animals, geographical location of slaughtering facilities, and regional location of production might alter the regional flows and prices of live slaughter animals.

The third part of the study used a model which was simultaneous in that it estimated least-cost flows of live slaughter animals and meat simultaneously (16). This latter model was designed to minimize the aggregate transportation and slaughtering cost. The analysis was performed under the restriction that the total supply of cattle and hogs over all regions when converted to beef and pork was specified to be equal to the total regional demands for the meat products. The results of the joint analysis illustrated that total transportation costs were substantially less when the livestock and meat sector were considered simultaneously. When only the existing structure of transportation rates for livestock and meat was considered, transportation rates were minimized by slaughtering the livestock at or near the producing areas.

Williams and Dietrich employed a transportation model in a study of interregional competition in the fed beef industry for 1960 (36). Spatial models were used to determine estimates of consumption for each of 20 regions, distribute available excess production to deficit markets by least-cost routes, and determine equilibrium prices for each region. A second model was used to determine the simultaneous optimum distribution of live fed cattle and dressed fed beef under the condition that shipping rates for live animals were significantly higher than rates on shipments of an equivalent quantity of dressed beef.

The findings produced by their analyses led Williams and Dietrich to several generalizations about locational advantage and transportation costs. First, location and transportation costs are important determinants of competitive market power in interregional commerce. Second, however, was that location relative to markets and regional differences in shipping costs to common deficit market destinations probably are not matters of overriding concern to shippers in most regions of the United States. Locational advantages relative to markets could be offset by lower factor (or raw material) prices or by more efficient rations, economies of size, lower taxes, lower insurance rates, depreciation, superior management, improved techniques, or other means. It was also suggested that the indicated opportunity transport costs may not greatly influence procurement patterns of large-volume wholesalers and retailers since other factors are important to buyers in deficit regions (36, p. 17).

Crom extended the three-part study by Judge, Havlicek, and Rizek, discussed above, in later projects (37). He used the simultaneous model developed in Part III of the original study for projection purposes. Projections of cattle and hog production for slaughter, beef, and pork consumption, slaughter capacity, transportation costs, and labor costs for slaughter in 26 regions of the continental U.S. provided a base solution for 1975. Then, shifts in data involving the transportation rate structure, distribution of production and consumption, and absence of slaughter capacity restrictions were assumed as a result of plausible changes in market organization in the 1970's. Optimal interregional trade was determined for each of these alternatives, and the results were compared with the 1975 base solution.

Concerning the transportation rate structure, a reduction in rail rates for longer hauls was hypothesized, and transportation and slaughter costs were reduced 5.5 percent as a result. The solution showed that beef shipping costs were 10 percent less than in the base, while shipping costs for live cattle were 6 percent less. However, interregional flows of both cattle and beef were generally the same as in the base solution. Crom felt that this indicated a low flexibility among potential suppliers of deficit areas.

Aylor and Juillerat used an interregional transportation model to make two- and three-dimensional analyses of the 1962 movements of cattle, beef, calves, and veal on both an annual and quarterly basis (1). As opposed to other studies reviewed in this chapter, the two-dimensional analysis generated very few optimal movements that were not toward the East and Northeast regions. The optimum movements in the southern areas were mostly between adjacent areas, while in other parts of the country the shipments were mostly to non-adjacent regions. The three-dimensional analysis used a generalized distribution model which included shipping, slaughtering, and processing costs. Slaughter was permitted to increase or decrease from the actual in 1962, and transportation costs were later increased 20 percent to investigate the stability of the cattle solution. All available quantities of cattle, calves, beef, and veal in each region were allowed to move; so, some regions in the solutions shipped to outside areas while they received shipments from other areas to satisfy their own requirements. The great majority of optimal shipments of all commodities were toward the East and Northeast.

Dietrich conducted a study to determine the least-cost locations and optimum levels of cattle feeding and fed-cattle slaughter among 27 regions, measure the effects of specified changes in regional feedlot size on the optimum locations and levels of feeding and slaughter, and show the least-cost shipment routes for feeder cattle, feed grain, fed slaughter cattle, and dressed fed beef for 1968 (4). The model used by Dietrich was a multidimensional transshipment model designed to minimize the combined costs of producing and moving fed beef from production through slaughter to consumption. The solutions revealed that the bulk of feeder cattle were shipped either to the Southwest and Southern Plains, or to Kansas, Nebraska, and the Corn Belt. Most fed cattle were shipped eastward from the Plains and Corn Belt. Fed beef distribution costs were minimized when regions west of a line running from the western edge of the Plains States through the center of the Texas Panhandle shipped to the West, and regions east of this line shipped to the Northeast, East, and East South Central markets. However, West Texas was able to ship to either the West, Southeast, or both.

Takayama and Judge developed and interpreted the classical transportation model and discussed an example of minimizing total transportation costs for interregional shipments of homogeneous commodities (31). The assumptions and restrictions of the model were discussed. Extensions of the model were also presented which could handle situations where total regional supplies are unequal to total regional demands, production costs and transportation costs are to be minimized, net revenue is to be maximized, and multiple commodities which are substitutes for each other are to be shipped.

In his doctoral dissertation, Sprott made a departure from most of the earlier studies by including intraregional transfer costs for both intermediate and final products in the swine sector of the economy for 1971 (30). The basis for his action was the assumption that intraregional charges will occur in regions which both ship and receive a homogeneous product. That is, Sprott refutes the assumption that products consumed out of local production do not require transporting since each region is represented by a point. Sprott used a transportation model to identify and analyze 1971 patterns of hog production, slaughter, and consumption for the U.S. by major regions. The author used only truck shipping rates in computing transportation charges for hogs and pork.

All of the studies and research reviewed in this chapter utilized a linear programming transportation model, either two-dimensional or multidimensional, to obtain least-cost shipping patterns. However, this study differs from previous ones in that the regional breakdown is much more extensive and the main objective is to identify potential energy savings.

CHAPTER III

CONCEPTUAL FRAMEWORK

Cattle and beef are produced and consumed in differing amounts in each of the geographical districts employed in this study. In addition, cattle may be shipped several times before they reach the final consumer in the form of beef. It is assumed that every producer has the economic goal of profit-maximization and that every consumer has the goal of obtaining a desired amount of product at the least possible cost. However, some districts produce more cattle or beef than consumers in those districts are willing to buy at the prevailing prices, while other districts produce less than enough of these commodities to satisfy consumers' requirements at the prevailing prices. As a result, both producers and consumers would benefit if the surplus producing districts transported enough cattle and beef to the deficit consuming districts to fulfill the requirements which exist at the prevailing prices in the deficit districts.

Due to the stages of production through which cattle travel, the product cannot be shipped directly from a surplus producing area to a deficit consuming area. As was stated in Chapter I, most cattle are shipped from the farm or ranch to the feedlot and then to slaughter or packing-house. This route involves two separate movements before the product is in the proper form to be transported to the final consumer. When this movement from slaughter to consumer is considered in addition to the previous two movements, and the distances involved are taken into account, the possibility for inefficient use of fuel becomes apparent. This inefficiency is particularly clear when it is noted that the least-cost shipping routes under the 1976 rate structure did not necessarily coincide with the routes which would minimize fuel consumption in most cases.

In order to analyze this problem more carefully, it is necessary to begin with a simplified case. A simple two-region illustration will suffice to explain the conditions under which both producers and consumers could benefit by shipping a homogeneous product from excess regions to deficit regions. The product shipped between the two regions will be restricted to beef, for the sake of simplicity. It is assumed that beef is a homogeneous product. In reality, beef is not truly homogeneous due to government grading practices. However, the meat is shipped and traded as if it were a homogeneous commodity.

Assume that beef is produced and consumed in geographical regions A and B and that the demand and supply curves are known in each region. In Figure 1 the demand and supply curves for region B, D_B and S_B, respectively, are plotted on the right half of the figure in conventional form. However, the demand and supply curves for region A, D_A and S_A, respectively, have been reversed on the left half of the figure. Quantities of beef for region B are measured to the right of origin O, while quantities for region A are measured to the left of the origin. The excess-supply curve for region B, ES_B, represents the amount by which the quantity of beef offered for sale exceeds the quantity of beef purchased at various price levels in region B. The excess demand curve for region A, ED_A, represents the amount by which the quantity of beef desired by consumers exceeds the quantity of beef offered for sale at various price levels in region A. In the absence of trade between A and B, the demand and supply curves determine the price of beef in each region. It can be seen from Figure 1 that the equilibrium price of beef in region A, OP_A, is relatively higher than the equilibrium price in region B, OP_B. These prices and the corresponding quantities would represent equilibrium conditions under the assumption of no interregional trade of beef. On the other hand, assuming no trade barriers and no costs of transportation, traders could profitably engage in arbitrage by purchasing the product in region B at a price of OP_B and selling it in region A at the relatively higher price of OP_A. The intersection of the curves ED_A and ES_B at point J represents the determination of OX, the equilibrium price with trade. The curve ED_A-ES_B represents

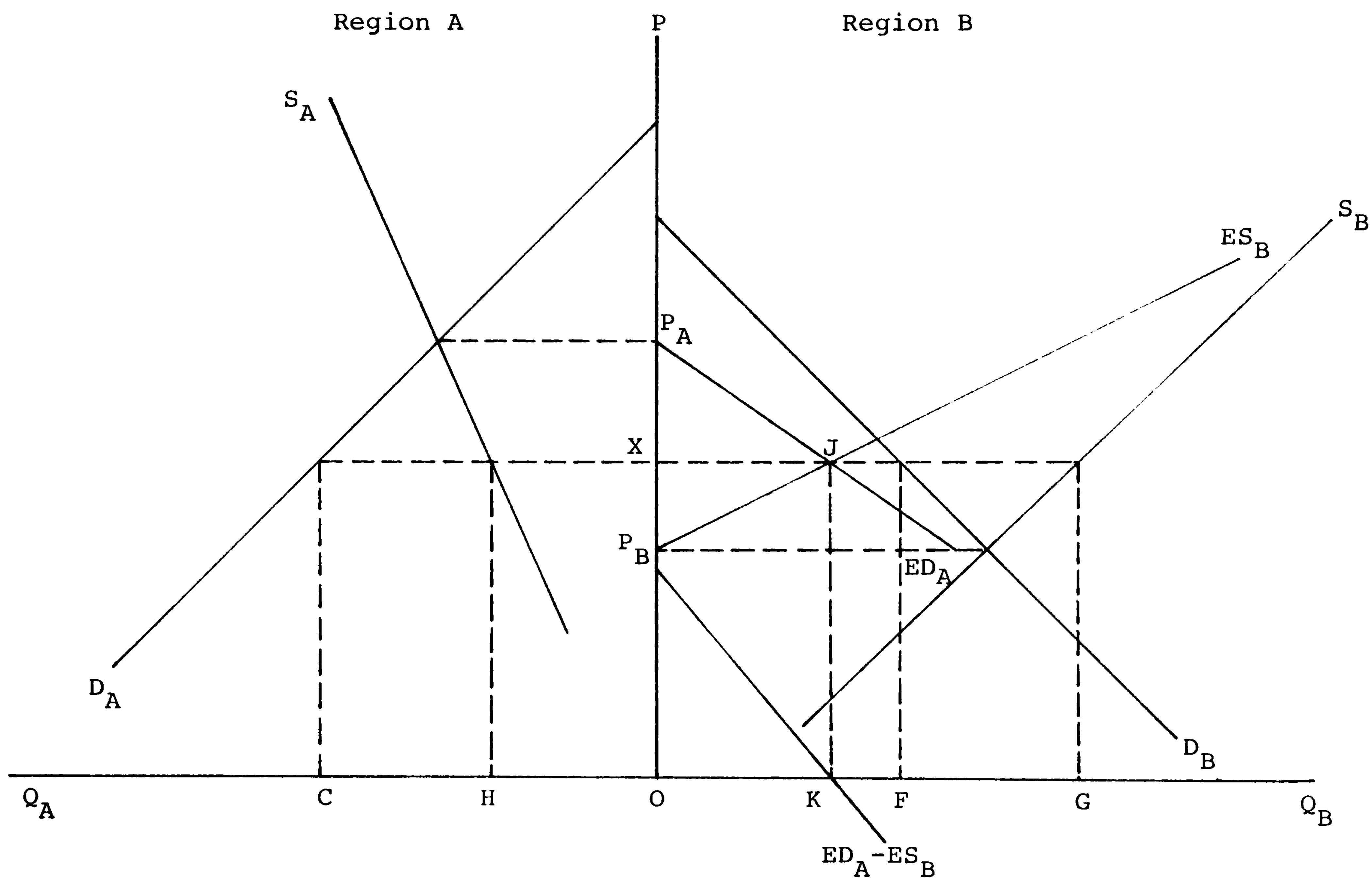

Figure 1. Interregional Trade with Zero Transportation Costs

the vertical distance between ED_A and ES_B. The intersection of ED_A-ES_B with Q_B at point K represents the amount of beef exported from region B to region A at equilibrium price OX. This amount, OK, is equal to the distance XJ, FG, and CH, and represents the quantity at which the excess demand of region A and excess supply of region B are equal. Inter-regional trade will continue as long as the price in A exceeds the price in B. Eventually, the flow of beef from region B to region A will be enough to equalize the price in each region at some point between the original equilibrium prices, OP_B and OP_A, respectively.

However, the assumption of no transportation costs is an over-simplification. In reality, positive transportation costs exist and include any costs involved in the transfer of a commodity from one region to another. As a result, a trader buying beef in region B must include in his costs the cost of shipping the beef from region B to region A. In order to make a profit from his arbitrage, the trader must receive a price which is at least equal to or greater than the sum of the price in region B and the transportation costs.

Assume that the cost of transportation per unit of beef is T. With the addition of this positive transfer cost, the equilibrium price in the exporting region will be lower than the equilibrium price in the importing region by the amount of the transfer cost. Figure 2 shows the same demand and supply curves as Figure 1 after adjustments were made for the transportation cost. In Figure 2 the supply, demand, and excess supply curves for region B--the exporting region--have been moved upward by the amount T representing the unit cost of interregional transfer. The effect of this shift is to add the unit transfer cost to the unit price of the beef in region B. It is apparent that the equilibrium price in region B, O'X', is less than region A's equilibrium price, OX'. By adding the unit cost of transportation to the equilibrium price of region B, the resulting sum, OX', is equal to the equilibrium price of region A. Therefore, the equilibrium prices in regions A and B differ by the unit transportation cost. In Figure 2 the determination of the amount of beef exported from region B to region A is performed just as it was in Figure 1. The intersection of ES_B and ED_A at J' sets the equilibrium prices at O'X' in B and OX' in A. The intersection of ED_A-ES_B with Q_B at K' sets the amount of beef transported from region B to region A at O'K' which is also equal to X'J', F'G' and C'H'. Trading will continue as long as the price in region A exceeds the sum of the price in region B and the transfer cost.

Bressler and King note that widely separated regions may not engage in trading because the costs of transfer exceed the price differences that exist in absence of trade.

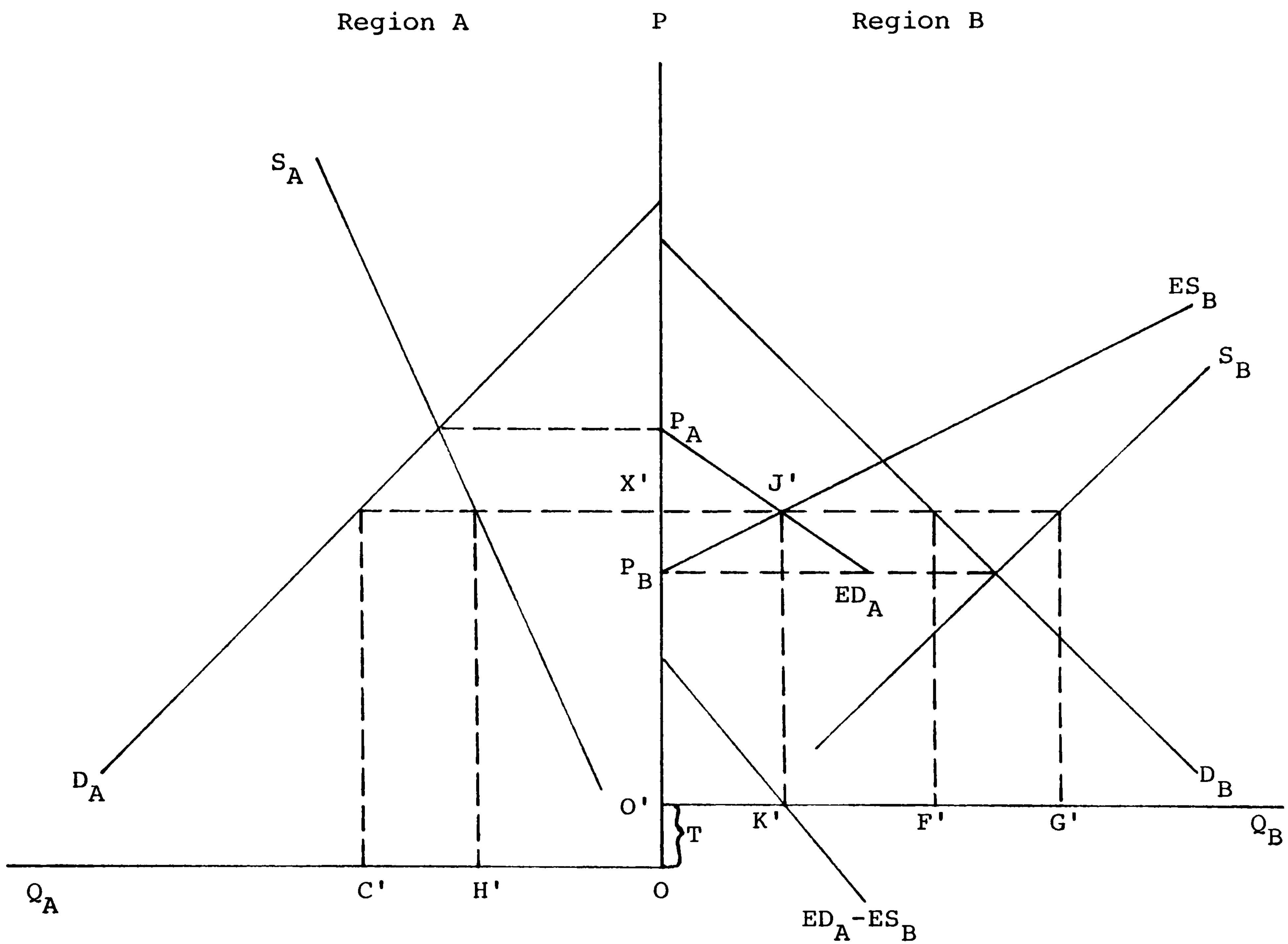

Figure 2. Interregional Trade with Positive Transportation Costs

Therefore, great distances and expensive transportation restrict trade while technological developments that reduce transfer costs can increase trade (2, p. 92).

Analysis becomes more complex when the problem is expanded to a multi-regional study. Identification of importing and exporting regions, quantities shipped, and which region should ship available surplus to which deficit region become very complicated tasks. Consideration of transportation costs causes the pattern of distribution of the commodity to become an essential factor in determining the total transportation costs. As Sasieni, Yaspan, and Friedman have noted,

> Problems of allocation arise whenever there are a number of activities to perform, but limitations on either the amount of resources or the way they can be spent prevent us from performing each separate activity in the most effective way conceivable. In such situations we wish to allot the available resources to the activities in a way that will optimize the total effectiveness.
> (29, p. 183)

Least-cost allocations (shipping routes) may not necessarily consist of shipments traveling from one district to neighboring districts. This fact is due to the nature of production and consumption in each district and to the assumption that a surplus district can ship only to a deficit district. It is possible that one surplus producing district could be surrounded by other surplus producing districts. In this case the least-cost solution may result in the former district shipping to more distant districts. Conversely, one deficit district surrounded by other deficit districts might be forced to receive shipments from distant surplus districts. Another possibility is that the deficit of a particular district may be greater than the surplus of any neighboring district or districts. In such a situation it would be necessary for the deficit district to receive shipments from more distant surplus districts. The same type of logic could be applied to a district whose surplus is greater than the combined deficits of neighboring districts.

Accurate district supply and demand functions for any commodity are very difficult to estimate; so, predetermined estimates of the quantity available for shipment and required in each district must be used. As a result, district surpluses and deficits are not a function of price. The surplus or deficit of each district can be determined through the use of these predetermined estimates of quantities shipped and consumed.

With the above stated information, linear programming can be used to obtain the optimum distribution pattern which minimizes total transportation costs. This pattern is consistent with the economic goals of producers and consumers. Transportation costs add to the total costs faced by producers and the final price paid by consumers. Therefore, minimization of transfer costs is in the economic interest of both parties.

The major assumptions and restrictions which must be made in order to use a linear programming transportation model to determine cost-minimizing shipments are as follows:

a. the commodity traded is a homogeneous product produced under purely competitive conditions so that consumers are indifferent to the original source of the commodity;

b. each producer has the goal of profit maximization;

c. all districts engaging in trade are connected by known unit transportation costs which are independent of the direction and volume of trade;

d. district quantities of the commodity available for shipment and required are known or predetermined;

e. district surpluses or deficits exist at only one point in the district;

f. the total amount of product shipped from an origin cannot exceed the total surplus of that district;

g. the total amount received by a destination must not be greater than the total deficit of that district;

h. surplus districts may ship only to deficit districts, and deficit districts may receive only from surplus districts (i.e., no cross-hauling of the commodity is allowed);

i. all shipments are one-way from surplus to deficit districts.

The transportation problem becomes more complex when the commodity being shipped has intermediate destinations. In this case, live cattle must be converted into beef before the product is suitable for consumption. Cattle may be produced in one district, fed to slaughter weight in another district, slaughtered and packed in a third district, and consumed in a fourth district. Therefore, the objective of the transportation problem in this instance was to minimize the total cost of transporting live cattle and beef. This was to be accomplished by allowing production and feeding districts to ship live cattle while slaughtering districts shipped dressed beef. However, due to data incompatability, it was necessary to run each movement of live cattle and beef as a separate transportation problem, instead of including all movements in a simultaneous transshipment model. That is, separate runs were made for the movement of cattle from production to feeding districts, from feeding to slaughter districts, and so on. Therefore, the total transportation costs for each shipping movement were minimized separately. Linear programming and all the previously discussed assumptions and restrictions apply in this situation.

Two shipping rate structures have been employed in this analysis. The first rate structure consists of a combination of shipping rates actually used in 1976, where available, and rates estimated as a function of distance. Since, as Koopmans has noted (20, p. 257), government regulations have resulted in rates that are not necessarily a function of the shipping distance, the unit costs are minimized instead of the distance. The higher mileage which may be required to minimize total transfer costs consequently leads to greater fuel consumption. By applying fuel consumption estimates on a per-mile basis to the total mileage produced in this optimal solution, an estimate of the total fuel consumption required for the solution can be derived.

The second rate structure consists of unit costs which are forced to be a function of the distance traveled. Higher total transportation costs result from greater shipping distances in this case. Therefore, shipping distances must be minimized to minimize total transportation costs. Once again, fuel consumption estimates applied to the optimal mileage of the second solution give an estimate of the total fuel consumption required for the solution.

Comparison of the two total fuel consumption estimates derived from the optimal solutions gives an indication of potential petroleum fuel savings. These savings would be the result of using shipping rates that more directly reflect the actual costs of transportation instead of the rates applied in 1976.

CHAPTER IV

METHODOLOGY

Several of the 48 continental states have regulations governing the transportation of agricultural products, including shipping rates, when the transportation is intrastate.[1] To fully ascertain the implication of the intrastate rate structure upon the efficient use of fuel in transporting agricultural products, it was essential that the study be of sufficient detail to reflect this implication. The data also had to be at this level. Some of the data required for the study were obtained directly from published sources. However, much of the data was not available in published form, necessitating the employment of methods to estimate these data. This chapter, thus, deals with the details of district demarcation, estimation of necessary data, and the computer model employed in this study.[2]

District Demarcation

The continental United States were divided into 148 production and feeding districts and 89 slaughter and

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[1]See pp. 68-69 for a more detailed discussion.

[2]The complete data used in this study are not presented in this analysis due to the volume of the material but are on file with the Department of Agricultural Economics, Texas Tech University, Lubbock, Texas.

consumption districts for the purpose of this analysis. The object was to make the study as comprehensive as possible in order to obtain an accurate estimate of potential fuel conservation. However, due to unavailability of data, the above numbers of districts were the greatest amount of districts that could be retained with data of sufficient detail. Districts consisted of one or more U.S.D.A. crop reporting districts in each state. Table 1 shows the breakdown of these districts. District demarcation was based on the data availability and concentration of production-feeding or slaughter-consumption activity. Data on January 1 cattle inventory, annual cattle production, cattle on feed and fed-cattle marketings were either more readily available from published sources or more readily estimatable on a smaller geographical unit than the data on cattle slaughter and beef consumption. Thus, it was possible to have 148 total districts for the production-feeding portion of the study. However, it was necessary to reduce the total number of districts to 89 districts for the slaughter-consumption portion of the study. The reduction in the number of districts from 148 to 89 was accomplished by combining two or more production-feeding districts into one slaughter-consumption district whenever this was necessary due to the availability of data. When two or more production-feeding districts were combined to make one slaughter-consumption district, this was indicated on Table 1 by using braces, (}), or lines. A major city in each district was selected to represent the shipping-receiving point of the district. The selection of the cities was made on the basis of the amount of production-feeding or slaughter-consumption activity in or near cities which are close to the geographical center of the district.

For each of the districts, estimates of inventory, production, cattle on feed, fed cattle marketed, slaughter and consumption for 1976 were developed or obtained from published sources. In most instances, state totals were available, but district totals had to be estimated for several variables.

District Inventory and Production Estimates

State total estimates of cattle and calf inventory numbers for January 1, 1976, were obtained from a U.S.D.A. publication (35). However, this data was not on a basis smaller than state totals. Therefore, state publications were used to provide county estimates for the 13 states which were broken down into U.S.D.A. crop-reporting districts. These county estimates were then summed to provide district totals.

For purposes of the analysis, the continental United States was assumed to be a "closed" system. That is, no

TABLE 1.--Production-Feeding and Slaughter-Consumption Districts and Centers

Production-Feeding (PF) District	CRD*	Center	Slaughter-Consumption (SC) District	Center
		TEXAS		
1PF	1-N	Amarillo	1SC	Amarillo
2PF	1-S	Lubbock	2SC	Lubbock
3PF	2-N	Childress		
4PF	2-S	Abilene	3SC	Graham
5PF	3	Graham		
6PF	4	Dallas	4SC	Dallas
7PF	5-N	Tyler	5SC	Tyler
8PF	5-S	Huntsville		
9PF	6	Ft. Stockton	6SC	Ft. Stockton
10PF	7	San Angelo		
11PF	8-N	San Antonio		
12PF	8-S	Corpus Christi	7SC	San Antonio
13PF	9	Houston		
14PF	10-N	Laredo	8SC	Laredo
15PF	10-S	McAllen		
		IOWA		
16PF	NW	Spencer	9SC	Spencer
17PF	NC	Mason City		
18PF	NE	Decorah		
19PF	WC	Denison	10SC	Denison
20PF	C	Des Moines	11SC	Des Moines
21PF	EC	Cedar Rapids	12SC	Cedar Rapids
22PF	SW	Red Oak		
23PF	SC	Osceola		
24PF	SE	Burlington		
		NEBRASKA		
25PF	NW	Scottsbluff	13SC	Valentine
26PF	N	Valentine		
27PF	NE	Norfolk	14SC	Norfolk
28PF	C	Grand Island	15SC	Grand Island
29PF	E	Omaha	16SC	Omaha

TABLE 1--Continued

Production-Feeding (PF) District	CRD*	Center	Slaughter-Consumption (SC) District	Center
		NEBRASKA--Continued		
30PF	SW	North Platte	17SC	Holdredge
31PF	S	Holdredge		
32PF	SE	Beatrice	18SC	Beatrice
		KANSAS		
33PF	NW	St. Francis		
34PF	WC	Tribune		
35PF	SW	Liberal	19SC	Salina
36PF	NC	Concordia		
37PF	C	Salina		
38PF	SC	Wichita	20SC	Wichita
39PF	NE	Atchison	21SC	Topeka
40PF	EC	Topeka		
41PF	SE	Independence		
		MISSOURI		
42PF	NW	St. Joseph	22SC	St. Joseph
43PF	NC	Kirksville	23SC	Kirksville
44PF	NE	Hannibal	24SC	Hannibal
45PF	WC	Kansas City	25SC	Kansas City
46PF	C	Jefferson City	26SC	Jefferson City
47PF	EC	St. Louis	27SC	St. Louis
48PF	SW	Joplin	28SC	Joplin
49PF	SC	West Plains	29SC	West Plains
50PF	SE	Sikeston	30SC	Sikeston
		OKLAHOMA		
51PF	Panhandle	Guymon		
52PF	WC	Clinton		
53PF	SW	Lawton		
54PF	NC	Enid		
55PF	C	Oklahoma City	31SC	Oklahoma City
56PF	SC	Ardmore		
57PF	NE	Tulsa		
58PF	EC	Muskogee		
59PF	SE	Hugo		

TABLE 1--Continued

Production-Feeding (PF) District	CRD*	Center	Slaughter-Consumption (SC) District	Center
		CALIFORNIA		
60PF	(1)	Eureka	32SC	Redding
61PF	(2)	Redding		
62PF	(3)	Alturas		
63PF	(4)	San Jose	33SC	San Jose
64PF	(5)	Sacramento	34SC	Sacramento
65PF	(6)	Fresno	35SC	Fresno
66PF	(7)	Bridgeport		
67PF	(8)	Los Angeles	36SC	Los Angeles
		WISCONSIN		
68PF	NW	Hayward	37SC	Wisconsin Rapids
69PF	NC	Rhinelander		
70PF	NE	Marinette		
71PF	WC	Eau Claire		
72PF	C	Wisconsin Rapids		
73PF	EC	Oshkosh		
74PF	SW	Prairie du Chien	38SC	Madison
75PF	SC	Madison		
76PF	SE	Milwaukee		
		MINNESOTA		
77PF	NW	Crookston	39SC	Bemidji
78PF	NC	Bemidji		
79PF	NE	Hibbing		
80PF	WC	Fergus Falls	40SC	Fergus Falls
81PF	C	St. Cloud	41SC	St. Cloud
82PF	EC	Minneapolis	42SC	Minneapolis
83PF	SW	Worthington	43SC	Worthington
84PF	SC	Mankato	44SC	Mankato
85PF	SE	Rochester	45SC	Rochester

TABLE 1--Continued

Production-Feeding (PF) District	CRD*	Center	Slaughter-Consumption (SC) District	Center
		SOUTH DAKOTA		
86PF	NW	Bison		
87PF	NC	Aberdeen		
88PF	NE	Watertown		
89PF	WC	Rapid City		
90PF	C	Huron	46SC	Huron
91PF	EC	Sioux Falls		
92PF	SW	Hot Springs		
93PF	SC	Winner		
94PF	SE	Yankton		
		COLORADO		
95PF	NW & Mountains	Craig	47SC	Craig
96PF	NE	Greeley	48SC	Greeley
97PF	EC	Denver	49SC	Denver
98PF	SW	Grand Junction	50SC	Alamosa
99PF	San Luis Valley	Alamosa		
100PF	SE	Pueblo	51SC	Pueblo
		ILLINOIS		
101PF	NW	Dixon	52SC	Dixon
102PF	NE	Chicago		
103PF	W	Quincy		
104PF	C	Bloomington		
105PF	E	Champaign		
106PF	WSW	Springfield	53SC	Springfield
107PF	ESE	Effingham		
108PF	SW	Chester		
109PF	SE	Mt. Vernon		
		ARIZONA		
110PF	N	Flagstaff		
111PF	SC	Phoenix	54SC	Flagstaff
112PF	SE	Tucson		
113PF	SW	Yuma		

The remaining regions consist of states which were not divided into crop reporting districts, i.e., each of the remaining states is reported as a single district. The following production-feeding districts are identical to the remaining slaughter-consumption regions.

TABLE 1--Continued

Region	State	Center	Region
114PF	New Mexico	Albuquerque	55SC
115PF	Utah	Salt Lake City	56SC
116PF	Washington	Seattle	57SC
117PF	Oregon	Bend	58SC
118PF	Montana	Great Falls	59SC
119PF	Wyoming	Casper	60SC
120PF	Idaho	Boise	61SC
121PF	North Dakota	Bismark	62SC
122PF	Arkansas	Little Rock	63SC
123PF	North Carolina	Raleigh	64SC
124PF	Louisiana	Baton Rouge	65SC
125PF	Michigan	Lansing	66SC
126PF	Indiana	Indianapolis	67SC
127PF	Mississippi	Jackson	68SC
128PF	Tennessee	Nashville	69SC
129PF	Kentucky	Lexington	70SC
130PF	Alabama	Montgomery	71SC
131PF	Georgia	Atlanta	72SC
132PF	Florida	Orlando	73SC
133PF	South Carolina	Columbia	74SC
134PF	Virginia	Richmond	75SC
135PF	West Virginia	Charleston	76SC

TABLE 1--Continued

Region	State	Center	Region
136PF	Maryland	Baltimore	77SC
137PF	Ohio	Columbus	78SC
138PF	Delaware	Dover	79SC
139PF	New Jersey	Trenton	80SC
140PF	Pennsylvania	Harrisburg	81SC
141PF	New York	Syracuse	82SC
142PF	Vermont	Montpelier	83SC
143PF	Massachusetts	Boston	84SC
144PF	Connecticut	Hartford	85SC
145PF	Maine	Augusta	86SC
146PF	Rhode Island	Providence	87SC
147PF	New Hampshire	Concord	88SC
148PF	Nevada	Winnemucca	89SC

*CRD refers to each state's crop reporting districts. Braces, }, or lines were used to identify production-feeding districts that were included in slaughter-consumption districts.

exporting or importing was allowed between the continental United States and Alaska, Hawaii, and any area outside the borders of the United States. Under this assumption, only intrastate and interstate shipments were allowed, and production, feeding, slaughter, and consumption totals for the continental United States for 1976 were all forced to equal each other. Therefore, cattle produced in the 48 states were fed, slaughtered and consumed in the 48 states. This was to simplify statistical analysis and focused the attention of the study on shipments within the confines of the continental United States. It also assured that the requirements of each destination could be filled with domestic products, thereby avoiding consideration of imports. Implicit in the equality of production, feeding, slaughter, and consumption totals is the assumption that there is a time lag of less than a year between production and consumption. This may not be realistic, but it was necessary since this study dealt only with the year 1976 with no consideration given to carryover.

Under the assumption of the 48 states being a "closed" system, the published U.S.D.A. estimates of state total cattle and calf production (35) were increased in order to agree with U.S.D.A.-reported total commercial cattle slaughter estimates for the continental 48 states for 1976. Equation 1 below was used to adjust production upward to agree with total commercial cattle slaughter estimates for 48 states.

$$AF = \frac{CCS_o}{PROD_o} \qquad \text{(Eq. 1)}$$

where:

CCS_o = total 48-state commercial cattle slaughter, 1,000 lbs.;

$PROD_o$ = published 48-state total cattle production, 1,000 lbs.;

AF = adjustment factor.

Another reason for this adjustment is the assumption that very few live cattle are imported to be fed and then slaughtered. Estimated district inventory was used as a basis to apportion liveweight production among districts by the use of Equation 2:

$$PROD_{ij} = \frac{INV_{ij}}{INV_j} \times PROD_j \qquad \text{(Eq. 2)}$$

where:

INV_{ij} = i-th district inventory in the j-th state, 1,000 head;

INV_j = j-th state total inventory, 1,000 head;

$PROD_j$ = j-th state total production, 1,000 lbs. liveweight;

$PROD_{ij}$ = i-th district production in the j-th state, 1,000 lbs., liveweight.

It was assumed that district production was directly proportional to district inventory. While this relationship may not exist in reality, the assumption insured that there would be minimal movement of cattle within and between districts. Therefore, fuel use by shippers was minimized, and fuel conservation estimates resulting from this analysis were as conservative as possible. In reality, petroleum fuel conservation could be greater.

District Cattle on Feed Estimates

Cattle and calves on feed as of January 1, 1976, were estimated for 41 of the 48 states (35). Estimates for Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, Delaware, and Alaska were grouped together under "Other States" with a total of 3,000 head. Equation 3 was used to develop an index to apportion the 3,000 head total among the seven relevant states. The resulting equation was:

$$COF_j = \frac{OH_j + S_j}{(OH_j + S_j)_o} \times COF_o; \; j = 1, 2, \ldots, 8 \qquad \text{(Eq. 3)}$$

where:

OH_j = number of heifers, 500 lbs. and over, that have not calved and are not used for replacement, in the j-th state, 1,000 head, as of Jan. 1, 1976;

S_j = number of steers, 500 lbs. and over, in the j-th state, 1,000 head, as of Jan. 1, 1976;

$(OH_j + S_j)_o$ = 8-state total of OH_j and S_j;

COF_o = 8-state total of cattle on feed, 1,000 head;

COF_j = state total of cattle on feed in the j-th state, 1,000 head.

Weight categories of 500 pounds and over were chosen because most cattle are moved to feedlots when they have attained a weight in the 450-750 pounds range. Heifers that have not calved and are not used for replacement and steers were selected because these cattle make up the majority of cattle placed on feed.

The state totals of cattle on feed resulting from the use of the index described above along with the other published state totals were apportioned among the state districts in the same manner as was explained above for district production; see Eq. 2.

District Fed Cattle Marketed Estimates

Fed cattle marketed for 23 states for 1976 was reported by the U.S.D.A. (35). Under the advice of the Statistical Reporting Service of the U.S. Department of Agriculture, the 23-state total of fed cattle marketed was multiplied by 1.04 to obtain an estimate of 25.142 million head for the 48-state total of fed cattle marketed for 1976. The reported totals for 23 states were apportioned among the production-feeding districts in the same proportion as district cattle on feed estimates. However, the 967,000 head increment for the other 25 states was apportioned using Equation 4:

$$FCM_{ij} = \frac{COF_{ij}}{COF_{j_o}} \text{ X } 967 \qquad \text{(Eq. 4)}$$

where:

COF_{ij} = number of cattle on feed in the j-th state (from the 25-state group only), 1,000 head;

COF_{j_o} = 25-state total of cattle on feed, 1,000 head;

FCM_{ij} = number of fed cattle marketed in the i-th district in the j-th state (25-state group only), 1,000 head.

Cattle on feed was used to apportion fed cattle marketed among the districts because it was assumed that districts with heavier concentrations of cattle on feed would market greater numbers of fat cattle, while districts with a smaller number of cattle on feed would market comparatively fewer fat cattle.

Fed cattle marketed were then converted to liveweight equivalents to provide consistency with other estimates in the analysis. The U.S. average liveweight per head of federally inspected cattle slaughtered, 1,030 pounds per head (35), was used in this assumption that the majority of fed cattle marketed for slaughter are federally inspected. Estimates of fed cattle marketed were used only for feeding districts.

Inventory, production and cattle on feed estimates were also provided for slaughter-consumption districts. For several states, two or more production-feeding districts were combined to make one slaughter-consumption district.

District Slaughter Estimates

The number of cattle slaughtered in federally inspected plants by districts was made available from an unpublished data source. Commercial cattle slaughter numbers and liveweight equivalents consist of federally inspected slaughter and non-federally inspected slaughter. Therefore, total federally inspected cattle slaughter for a state could not exceed total commercial cattle slaughter for that state. In some cases, it was assumed that non-federally inspected slaughter for a state was equal to zero; so, federally inspected cattle slaughter could be equal to commercial cattle slaughter.

The 48-state total of federally inspected cattle slaughter numbers, 38,530,200, developed by the above procedure was less than the published total of federally inspected cattle slaughter for the 48 states, 38,964,800 head. The district cattle slaughter numbers were adjusted upward so that the correct 48-state total would be obtained by using the following equation:

$$AFIS_i = \frac{38,964.8}{38,530.2} \times FIS_i \qquad \text{(Eq. 5)}$$

where:

FIS_i = initial estimate of federally inspected cattle slaughter for the i-th district, 1,000 head;

$AFIS_i$ = adjusted estimate of district federally inspected cattle slaughter for the i-th district, 1,000 head.

The condition was imposed so that the federally inspected cattle slaughter total of a state would not exceed a maximum of the reported commercial slaughter for that state. If the federally inspected cattle slaughter for a state reached this maximum in the adjustment process, then it was removed from any further adjustment consideration, and the federally inspected cattle slaughter for that state was set at its maximum, commercial cattle slaughter. The adjustment process was then repeated, with the numerator of the conversion factor reduced by the commercial slaughter of the state removed. This adjustment process was continued until the proper total was obtained.

Non-federally inspected cattle slaughter numbers for states were estimated as the residual between commercial cattle slaughter and federally inspected cattle slaughter for states using Equations 6 and 7.

$$NFIS_j = CS_j - AFIS_j \qquad \text{(Eq. 6)}$$

and:

$$NFIS_{i_o} = CS_o - AFIS_{i_o} \qquad \text{(Eq. 7)}$$

where:

$AFIS_j$ = total adjusted federally inspected cattle slaughter for the j-th state, 1,000 head;

$NFIS_j$ = total non-federally inspected cattle slaughter for the j-th state, 1,000 head;

CS_j = reported total commercial cattle slaughter for the j-th state, 1,000 head;

$AFIS_{i_o}$ = total $AFIS_i$ (see Eq. 5) for all districts, 1,000 head;

$NFIS_{i_o}$ = total non-federally inspected cattle slaughter for all districts, 1,000 head;

CS_o = reported 48-state total commercial slaughter, 1,000 head.

State totals of non-federally inspected cattle slaughter were apportioned among the slaughter districts, based on the estimated district production, Equation 8:

$$NFIS_{ij} = \frac{P_{ij}}{P_j} \times NFIS_j \qquad \text{(Eq. 8)}$$

where:

P_{ij} = district production estimates in the i-th district of the j-th state, 1,000 lbs.;

P_j = state total production estimate for the j-th state, 1,000 lbs.;

$NFIS_j$ = state total non-federally inspected slaughter for the j-th state, 1,000 head;

$NFIS_{ij}$ = non-federally inspected slaughter in the i-th district of the j-th state, 1,000 head.

To obtain estimates of district federally inspected cattle slaughter in liveweight equivalents by districts, the original unadjusted slaughter numbers were multiplied by the U.S. average liveweight per head of federally inspected cattle slaughter, 1,030 lbs. This 48-state total proved to be less than the total computed with reported average liveweight and the 48-state total federally inspected slaughter numbers developed above. The same adjustment process used for federally inspected slaughter numbers was employed to increase the district liveweight estimates of federally inspected slaughter, Equation 9:

$$FISLW_{i_o} = TFISLW_r \qquad \text{(Eq. 9)}$$

where:

$FISLW_{i_o}$ = estimated total district liveweight of federally inspected slaughter, as computed from the adjustment procedure, 1,000 lbs.;

$TFISLW_r$ = reported total liveweight of federally inspected slaughter for 48 states, 1,000 lbs.

Non-federally inspected cattle slaughter in liveweight equivalents was assumed to be the difference between commercial slaughter liveweight and federally inspected slaughter liveweight. Therefore:

$$CSLW_j = FISLW_j + NFISLW_j \qquad \text{(Eq. 10)}$$

and:

$$TCSLW = \Sigma(FISLW_i + NFISLW_i) \qquad \text{(Eq. 11)}$$

where:

$FISLW_j$ = total liveweight federally inspected slaughter for the j-th state, 1,000 lbs.;

$NFISLW_j$ = total liveweight non-federally inspected slaughter for the j-th state, 1,000 lbs.;

$CSLW_j$ = total liveweight commercial slaughter for the j-th state, 1,000 lbs.;

$\Sigma(FISLW_i + NFISLW_i)$ = total combined district federally inspected and district non-federally inspected slaughter for all districts, 1,000 lbs. liveweight;

$TCSLW$ = reported 48-state total commercial slaughter, 1,000 lbs. liveweight.

State totals of non-federally inspected slaughter, liveweight, were apportioned among the slaughter districts in a state in the same manner used for district non-federally inspected slaughter numbers.

District Beef Consumption Estimates

District consumption estimates of beef were developed through the use of (1) cross-sectional beef consumption indexes--U.S. civilian per capita consumption estimates for beef, and (2) 1975 estimates of consumption district populations. Cross-sectional indexes indicate the percentage of civilian per capita consumption that occurred in four areas of the country (33). Civilian per capita consumption (35) was multiplied by the applicable index for each state to obtain district per capita consumption for the various states. This product was then multiplied by the relevant 1975 estimated consumption district population (38). 1976 population estimates were not available at the time this part of the analysis was performed.

$$C_i = CSI_i \times PCC \times P_i \qquad \text{(Eq. 12)}$$

where:

CSI_i = cross-sectional beef consumption index applicable to the i-th consumption district;

PCC = U.S. civilian per capita beef consumption, pounds;

P_i = 1975 population of the i-th district, 1,000 pounds;

C_i = estimate of beef consumption for the i-th district, 1,000 pounds.

The resulting district beef consumption estimates were in carcass weight equivalents. The 48-state total consumption was less than the reported total after the available data for Hawaii and Alaska were deleted from the reported total. To increase the district estimates and convert them to liveweight equivalents, an adjustment factor was employed:

$$\frac{C_{o_f}}{C_{o_c}} \text{ X } C_i = AC_i \qquad \text{(Eq. 13)}$$

where:

C_{o_f} = 48-state total beef consumption which is consistent with production, feeding and slaughter totals, liveweight equivalents, 1,000 lbs.;

C_{o_c} = estimated initial 48-state total beef consumption, carcass weight equivalents, 1,000 lbs.;

C_i = original district beef consumption estimates, 1,000 lbs.;

AC_i = adjusted district beef consumption, liveweight equivalents, 1,000 lbs.

Revised District Estimates

It was originally intended to use the district estimates of production, fed cattle marketed, slaughter, and consumption in the linear programming transportation model. However, due to insufficient data, non-fed cattle marketed for slaughter could not be quantified through production or slaughter. The data is not reported in any source used in this analysis, and it could not be developed from any available data. As a result, total fed cattle marketed was less than the totals for production, slaughter and consumption. This meant that there were not enough cattle moving from feeding to slaughter to fill the total requirements of the slaughter districts.

It was assumed that non-fed cattle marketed would be the amount necessary to supply the unfulfilled slaughter requirements. Under this assumption it was decided to run the linear programming model in three parts:

(1) a "feeding" sector in which total production for feeding purposes (FP_o) equals total fed cattle marketed (FCM_o) which equals total fed cattle slaughtered (FCS_o);

(2) a "non-feeding" sector in which total production for non-feeding (or grass-feeding) purposes (NFP_o) equals total non-fed cattle marketed ($NFCM_o$) which, in turn, equals total non-fed cattle slaughtered ($NFCS_o$);

(3) a "slaughter-consumption" sector in which total commercial slaughter (TS_o) equals total consumption (TC_o).

All variables mentioned in the three sectors are in live-weight equivalents.

As a result of using this sector delineation:

$$NFP_o + FP_o = TP_o \qquad \text{(Eq. 14)}$$

$$NFCM_o + FCM_o = TM_o \qquad \text{(Eq. 15)}$$

$$NFCS_o + FCS_o = TS_o \qquad \text{(Eq. 16)}$$

where:

TP_o = estimated 48-state total production of cattle, 1,000 lbs.;

TM_o = estimated 48-state total cattle marketings for slaughter, 1,000 lbs.

It was assumed that FCS_o was equal to FCM_o since fed cattle marketed are assumed to be slaughtered as fat cattle. Therefore, $NFCS_o$ is equal to the difference between TS_o and FCM_o.

Also:

$$TP_o = TM_o = TS_o = TC_o = 43{,}383{,}623 \text{ thous. lbs.} \quad \text{(Eq. 17)}$$

District estimates for the non-feeding sector were obtained by using Equations 18 through 20:

$$NFP_i = NFP_o \times \frac{P_i}{TP_o} \quad \text{(Eq. 18)}$$

$$NFCM_i = NFP_i \quad \text{(Eq. 19)}$$

$$NFCS_i = NFCS_o \times \frac{FISLW_i}{FISLW_o} \quad \text{(Eq. 20)}$$

where:

NFP_i = district estimate of liveweight production for non-feeding purposes, 1,000 lbs.;

P_i = original district liveweight production estimate, 1,000 lbs.;

$NFCM_i$ = district liveweight estimate of non-fed cattle marketed for slaughter, 1,000 lbs.;

$NFCS_i$ = district liveweight estimate of non-fed cattle slaughtered, 1,000 lbs.;

$FISLW_i$ = original district estimate of federally inspected cattle slaughtered, liveweight equivalents, 1,000 lbs.;

$FISLW_o$ = original 48-state total of federally inspected cattle slaughtered.

The original district production estimates were used as a basis to apportion non-feeding production in order to preserve the original total production estimates for each district and state. District non-fed cattle marketed equals district non-feeding production under the assumption that grass-fed cattle were grazed as close to the production location as possible, i.e., in the same district. This result is also consistent with the assumption that inter-district shipments would be minimized in order to keep the fuel conservation estimates as conservative as possible. Federally inspected cattle slaughter was used as a basis to apportion non-fed cattle slaughter since more than 90 percent of total commercial slaughter was federally inspected in 1976. As a result, federally inspected slaughter must include the major portion of both fed and non-fed slaughter. Also, there was no available data which could indicate the concentration of federally and non-federally inspected slaughter facilities among the districts, or the factors which attract slaughter to federally inspected or non-federally inspected plants. Therefore, it was assumed that these factors were equal for federally inspected and non-federally inspected operations.

District estimates were obtained for the feeding sector as shown below:

$$FP_i = P_i - NFP_i \quad \text{(Eq. 21)}$$

$$FCS_i = TS_i - NFCS_i \quad \text{(Eq. 22)}$$

where:

FP_i = district liveweight estimate of production feeding purposes, 1,000 lbs.;

FCS_i = district liveweight estimate of fed cattle slaughtered, 1,000 lbs.;

TS_i = district liveweight estimate of commercial cattle slaughtered, 1,000 lbs.

The district estimation of fed cattle marketed (FCM_i) was explained previously.

The slaughter-consumption sector was not changed from the previous district estimates for commercial slaughter and consumption.

District Surplus or Deficit

The determination of each district as a surplus shipping district or a deficit receiving district, and the amount of the district surplus or deficit, was necessary to provide constraints for the LP transportation model.

For the movement from production to feeding, the difference between district production for feeding purposes (FP_i) and district fed cattle marketed (FCM_i) was calculated. If FP_i exceeded FCM_i, the district had surplus production which could be shipped to other districts. Conversely, if FCM_i exceeded FP_i, the district had to fill its deficit of marketings from other producing districts. The calculated surpluses and deficits were used as the district constraints in the computer models.

The above method was applied in a similar manner to the feeding and non-feeding sectors for the movements from feeding (or non-feeding) to slaughter, and from total slaughter to total consumption. However, it was unnecessary to analyze any movement from production for grass-feeding purposes to grazing areas since it was earlier assumed that such grazing areas were in the same district as the production location. Therefore, there were no inter-district shipments in this portion of the non-feeding sector under this assumption.

Surpluses and deficits of both fed and non-fed cattle marketed for slaughter could not be calculated for the 148 production-feeding districts. The reason was that district slaughter estimates were calculated for the 89 slaughter-consumption districts, but there was no method available to apportion the slaughter estimates over 148 districts. The district slaughter estimates were not based upon production, inventory, or feeding estimates. Therefore, estimates of fed and non-fed cattle marketed for slaughter in 148 districts had to be combined for estimates for 89 districts. District surpluses and deficits could then be calculated. Movements of both fed cattle and non-fed cattle to slaughter locations were also analyzed in this manner. It was assumed that cattle in the feeding and non-feeding sectors were aggregated from 148 districts to 89 districts. Then shipments of surplus cattle among 89 districts in both sectors were analyzed.

Transportation Costs

Transportation costs were considered for shipments of live cattle and dressed beef by truck only. Intrastate shipping rates for live cattle were obtained from regulatory agencies from 19 of the 13 states which are divided into more than one production-feeding district. Livestock shipments by truck are unregulated in Missouri, Minnesota, Oklahoma, Nebraska, and Wisconsin, but shippers file their individual rates in Missouri and Oklahoma. Intrastate rates for meat were obtained from 9 of the 10 states that were divided into more than one slaughter-consumption district. Minnesota, Missouri, Oklahoma, and Wisconsin do not regulate meat shipments by truck, but carriers file their individual rates in Missouri and Wisconsin. The intrastate rates that were obtained were applied to intrastate shipments for appropriate districts in the linear programming model.

Intrastate costs of shipping livestock for Nebraska, Wisconsin, and Minnesota and all interstate shipping costs of livestock were estimated as a function of distance transported. Costs of shipping live cattle were estimated as a function of the distance transported, using data collected from a survey of truckers in various states.

$$C_L = Z \times D \qquad \text{(Eq. 23)}$$

where:

C_L = cost of shipping live cattle, \$/10 cwt.;

Z = estimated constant cost of shipping live cattle, \$/mi./10 cwt.;

D = highway mileage between origin and destination.

This cost estimation was used in the movements from production to feeding and from feeding to slaughter. Another estimating equation with the square root of the mileage included as a variable was investigated. However, the analysis showed that the square foot of the mileage added very little to the regression.

Intrastate cost of shipping beef for Minnesota and all interstate shipping costs of beef were estimated as a function of the distance transported, also. Costs of shipping beef were estimated as a function of the distance transported, using data collected from a survey of truckers in Texas and New Mexico.

$$C_B = Y \times D \qquad \text{(Eq. 24)}$$

where:

C_B = cost of shipping beef, \$/mi./10 cwt.;

Y = estimated constant cost of shipping beef, \$/mi./10 cwt.;

D = highway mileage between origin and destination.

This equation was used in the movement from slaughter to consumption. As in the estimation of live cattle shipping costs, the square root of the distance added very little to the regression.

The Computer Model

Solutions to the several transportation problems described previously were obtained through the use of linear programming methods. District surpluses and deficits and interstate and intrastate shipping costs were computed as described in the previous sections.

A general description of the model used for each transportation problem in this analysis is given below:

B = beef, liveweight equivalents;

L = live cattle, liveweight equivalents;

i = districts which serve as shipping origins for live cattle or beef ($j = 1,2,\ldots,m$);

j = districts which are destinations for live cattle or beef ($j = 1,2,\ldots,n$);

S_i = excess quantity of live cattle or beef available for shipment from the i-th origin, in 1,000-lb. units;

d_j = quantity of live cattle or beef needed at the j-th destination, in 1,000-lb. units;

X_{ij} = quantity of live cattle or beef shipped from the i-th origin to the j-th destination, in 1,000-lb. units;

C_{ij} = cost per 1,000 lbs. of shipping live cattle or beef from the i-th origin to the j-th destination, either set by a state agency or estimated.

The objective of minimizing total costs of shipping live cattle and beef, under the restrictions and assumptions stated in Chapter III, can be stated with the above notation as:

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijL}X_{ijL} = \text{a minimum} \qquad \text{(Eq. 25)}$$

and:

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ijB}X_{ijB} = \text{a minimum} \qquad \text{(Eq. 26)}$$

The stated objective was accomplished after the following restraints were placed upon the model:

(1) $$\sum_{j=1}^{n} X_{ijL} \leq S_{iL} \quad (i = 1,2,\ldots,m) \qquad \text{(Eq. 27)}$$

The total shipments of live cattle from any surplus origin cannot exceed the total amount of excess live cattle at that district.

(2) $$\sum_{i=1}^{m} X_{ijL} \geq d_{jL} \quad (j = 1,2,\ldots,n) \qquad \text{(Eq. 28)}$$

The total shipments of live cattle to any deficit destination must be greater than or equal to the total requirement of live cattle at that district.

(3) $$\sum_{j=1}^{n} X_{ijB} \leq S_{iB} \quad (i = 1,2,\ldots,m) \qquad \text{(Eq. 29)}$$

The total shipments of beef from any surplus slaughter origin cannot exceed the total amount of excess beef at that district.

(4) $$\sum_{i=1}^{m} X_{ijB} \geq d_{jB} \quad (j = 1,2,\ldots,m) \qquad \text{(Eq. 30)}$$

The total shipments of beef to any deficit consumption destination must be greater than or equal to the total requirement of beef at that district.

Negative values would have no meaning in this type of problem; therefore, it is necessary that all

$$S_i \geq 0;\ d_j \geq 0;\ X_{ij} \geq 0 \qquad \text{(Eq. 31)}$$

for live cattle and beef.

Figure 3 shows a sample linear programming tableau utilizing the restraints described above. The eight sample districts bear no relationship to the districts actually used in this analysis. It is assumed that districts 1 through 4 have excess supplies of live cattle, while districts 5 through 8 are deficit in live cattle. Therefore, districts 1-4 represent live cattle origins, and districts 5-8 represent live cattle destinations. This hypothetical situation could be compared to the movement from feeding origins to slaughter destinations presented in this analysis.

The first four rows of the sample tableau illustrate the conditions imposed by the first restraint equation. None of the live cattle origins (districts 1-4) can export more than the total amount of excess live cattle in that district shown as S_{1L}, S_{2L}, S_{3L}, S_{4L}.

SHIPPING ACTIVITIES

		1,5	1,6	1,7	1,8	2,5	2,6	2,7	2,8	3,5	3,6	3,7	3,8	4,5	4,6	4,7	4,8	Restraints
Live	1	1	1	1	1													$\leq S_{1L}$
Cattle	2					1	1	1	1									$\leq S_{2L}$
Origins	3									1	1	1	1					$\leq S_{3L}$
	4													1	1	1	1	$\leq S_{4L}$
Live	5	1				1				1				1				$\geq d_{5L}$
Cattle	6		1				1				1				1			$\geq d_{6L}$
Destinations	7			1				1				1				1		$\geq d_{7L}$
	8				1				1				1				1	$\geq d_{8L}$
Cost		C_{15}	C_{16}	C_{17}	C_{18}	C_{25}	C_{26}	C_{27}	C_{28}	C_{35}	C_{36}	C_{37}	C_{38}	C_{45}	C_{46}	C_{47}	C_{48}	= Min.

Figure 3. Sample Linear Programming Tableau

The next four rows of the tableau represent the conditions imposed by the second restraint equation. Each of the live cattle destinations (districts 5-8) must receive a minimum of the total live cattle deficit in that district, shown as d_{5L}, d_{6L}, d_{7L}, d_{8L}.

The last row of the sample tableau shows the respective unit shipping costs for each shipping activity. Thus, if district 1 ships live cattle to district 5, it will incur a cost of C_{15} per unit.

This same type of example could be applied to shipments of beef, and the corresponding restraints, very easily.

Determination of Fuel Consumption

Three sectors (feeding, non-feeding, slaughter-consumption) were developed for this analysis. The optimal shipping movements of each sector were obtained under two different sets of conditions for each movement.

The first set of conditions forced the use of intrastate shipping rates in use in 1976 if available. As discussed previously, unavailable intrastate rates and all interstate rates were estimated as a function of the distance shipped. Thus, a combination of actual and estimated rates was used. The second set of conditions imposed the use of a system in which all shipping rates were estimated as a function of distance.

Optimal solutions produced under these two sets of conditions necessarily contained information from which total mileage figures could be derived. The optimal amount of shipping activity between each origin and each destination was divided by the average weight per load of the commodity in order to derive the number of trips required for each optimal activity. The number of trips for each activity was multiplied by the distance between the origin and destination to find the mileage required by each activity.

$$T_{ij} = \frac{X_{ij}}{AWH} \qquad \text{(Eq. 32)}$$

and:

$$TM_{ij} = T_{ij} \times D_{ij} \qquad \text{(Eq. 33)}$$

where:

X_{ij} = optimal shipping activity between origin i and destination j;

AWH = average weight per load of the commodity hauled, in 1,000 lbs. (39 for beef, 45 for cattle);

T_{ij} = number of trips between origin i and destination j;

D_{ij} = highway mileage per trip between origin i and destination j;

TM_{ij} = total highway mileage resulting from optimal shipping activity between origin i and destination j.

For livestock shipments, only diesel consumption of the tractor itself was computed. The total mileage for each optimal activity (TM_{ij}) was divided by an average figure for miles per gallon of diesel consumed. Trucker surveys led to the assumption that this figure was 4.25 mpg.

For beef shipments, it was necessary to consider diesel consumption of the refrigerator unit in addition to that of the tractor. Survey information led to the assumption that the average refrigerator unit consumes 0.75 gallons of diesel per hour. It was also assumed that the average time spent loading, unloading, and waiting was 8.0 hours per trip. ICC regulations require that drivers must rest for 8 hours after driving 10 hours. Therefore, an 8-hour layover period per trip was added for each 600 miles of highway mileage (D_{ij}). Even though it was assumed that 44 miles per hour was the average speed for each trip, it was assumed that a driver would put in extra time if, at the end of his 10-hour shift, he were within 50 miles of his destination. Thus, 600 miles was used, instead of 550 miles, for the stopping point. Since 55 mph was used as the average speed for each trip, the number of hours spent on the road was found by dividing the total highway mileage covered in each activity (TM_{ij}) by 55. It was assumed that a refrigerator unit would have to run constantly during loading, driving, overnight stops, waiting, and unloading. Therefore, diesel consumption for the refrigerator unit was derived as follows:

$$RHR_{ij} = TM_{ij} \div 55; \qquad \text{(Eq. 34)}$$

$$HRS_{ij} = RHR_{ij} + (8 \times T_{ij}). \qquad \text{(Eq. 35)}$$

If $600 > D_{ij} \leq 1{,}200$,

$$THR_{ij} = HRS_{ij} + (8 \times T_{ij}). \qquad \text{(Eq. 36)}$$

If $1{,}200 > D_{ij} \leq 1{,}800$,

$$THR_{ij} = HRS_{ij} + (16 \times T_{ij}). \qquad \text{(Eq. 37)}$$

$$RG_{ij} = 0.75 \times THR_{ij} \qquad \text{(Eq. 38)}$$

where:

RHR_{ij} = number of hours required to drive from origin i to destination j;

HRS_{ij} = sum of driving hours and hours required for waiting, loading, and unloading;

THR_{ij} = HRS_{ij} plus any 8-hour layover periods required;

RG_{ij} = gallons of diesel consumed by the refrigerator unit on trips from origin i to destination j during 1976.

Total diesel used by the tractor and refrigerator unit was derived by:

$$TG_{ij} = RG_{ij} + TRG_{ij} \qquad \text{(Eq. 39)}$$

where:

TRG_{ij} = gallons of diesel consumed by the tractor on trips from origin i to destination j during 1976;

TG_{ij} = total gallons of diesel used by the tractor and refrigerator unit on trips from district i to district j during 1976.

CHAPTER V

FINDINGS

The basic data used in the study (production of cattle by districts, cattle feeding activities by districts, slaughter activities by districts, and consumption of beef by districts for 1976 for the 48 states), estimated surpluses and deficits by districts, and the results of alternative transportation model runs for optimal solutions are presented in this chapter.

Basic Data

Table 2 contains cattle production for feeding, fed cattle marketed, and surplus or deficit by production-feeding districts. Of the 148 production-feeding districts, 98 showed surpluses and 50 showed deficits. The total surplus of the 98 districts was estimated at 10,664,724 thousand pounds. Since total surplus was assumed equal to total deficit, the total deficit was also estimated at 10,664,724 thousand pounds.

Most of the surplus of feeder cattle was concentrated in the southeastern and eastern parts of Texas and the Southeastern states (Mississippi, Tennessee, Kentucky, Alabama, Georgia, Florida, Arkansas, and Louisiana). These states accounted for 44.8 percent of the total surplus of feeder cattle. Most of the deficit of feeder cattle was concentrated

TABLE 2.--Cattle Production for Feeding, Fed Cattle Marketed, and Surplus or Deficit, by Production-Feeding Districts, 1976, 48 States

District	Production (FP_i)	Fed Cattle Marketed (FCM_i)	Surplus	Deficit
1PF	450,853	2,583,549		2,132,696
2PF	102,706	365,032		262,326
3PF	126,765	84,254	42,511	
4PF	123,328	226,806		103,478
5PF	241,601	49,646	191,955	
6PF	414,461	32,445	382,016	
7PF	359,874	4,326	355,548	
8PF	173,872	8,652	165,220	
9PF	98,056	248,436		150,380
10PF	212,285	58,298	153,987	
11PF	365,940	123,188	242,752	
12PF	36,392	25,956	10,436	
13PF	153,654	2,163	151,491	
14PF	247,667	205,176	42,491	
15PF	46,501	47,483		982
16PF	273,037	445,887		172,850
17PF	105,164	172,113		66,949
18PF	241,072	395,005		153,933
19PF	270,109	441,973		171,864
20PF	168,604	275,731		107,127

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
21PF	221,796	361,839		140,043
22PF	194,225	316,828		122,603
23PF	203,496	332,484		128,988
24PF	152,501	250,290		97,789
25PF	193,525	392,018		198,493
26PF	314,410	638,085		323,675
27PF	305,297	620,060		314,763
28PF	250,884	509,953		259,069
29PF	246,596	499,653		253,057
30PF	150,638	304,880		154,242
31PF	125,711	256,264		130,553
32PF	168,596	340,827		172,231
33PF	100,356	165,933		65,577
34PF	149,941	576,079		426,138
35PF	267,809	1,507,714		1,239,905
36PF	181,357	135,136	46,221	
37PF	188,171	301,069		112,898
38PF	186,757	208,575		21,818
39PF	130,662	40,273	90,389	
40PF	183,124	73,439	109,685	
41PF	239,421	168,302	71,119	
42PF	178,178	49,337	128,841	

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
43PF	146,850	41,097	105,753	
44PF	104,753	28,840	75,913	
45PF	151,745	42,539	109,206	
46PF	250,624	68,495	182,129	
47PF	93,005	26,059	66,946	
48PF	166,430	45,217	121,213	
49PF	165,451	45,217	120,234	
50PF	35,244	9,579	25,665	
51PF	125,502	68,392	57,110	
52PF	107,717	58,607	49,110	
53PF	117,014	63,448	53,566	
54PF	138,638	75,705	62,933	
55PF	213,616	114,742	98,874	
56PF	184,312	100,116	84,196	
57PF	205,128	109,901	95,227	
58PF	131,160	70,761	60,399	
59PF	70,330	36,668	33,662	
60PF	25,292	41,509		16,217
61PF	33,190	55,414		22,224
62PF	36,623	61,285		24,662
63PF	170,527	282,941		112,414
64PF	102,430	170,156		67,726

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
65PF	466,717	775,590		308,873
66PF	43,261	71,276		28,015
67PF	266,433	441,149		174,716
68PF	62,055	17,922	44,133	
69PF	60,107	17,922	42,185	
70PF	31,028	9,682	21,346	
71PF	103,240	30,282	72,958	
72PF	45,637	13,802	31,835	
73PF	93,639	27,604	66,035	
74PF	114,510	34,402	80,108	
75PF	94,336	27,604	66,732	
76PF	28,523	8,240	20,283	
77PF	94,304	80,855	13,449	
78PF	26,178	23,072	3,106	
79PF	4,149	3,811	338	
80PF	139,642	119,480	20,162	
81PF	206,899	179,117	27,782	
82PF	68,908	59,740	9,168	
83PF	157,347	134,827	22,520	
84PF	94,695	80,855	13,840	
85PF	170,251	146,363	23,888	
86PF	89,957	50,676	39,281	

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
87PF	151,507	84,975	66,532	
88PF	118,364	66,950	51,414	
89PF	82,855	45,732	37,123	
90PF	151,507	84,975	66,532	
91PF	165,710	93,112	72,598	
92PF	52,080	29,458	22,622	
93PF	106,528	58,813	47,715	
94PF	146,772	81,679	65,093	
95PF	85,729	-0-	85,729	
96PF	354,948	1,515,954		1,161,006
97PF	221,091	291,284		70,193
98PF	97,761	16,686	81,075	
99PF	46,625	19,158	27,467	
100PF	171,458	365,238		193,780
101PF	164,215	246,067		81,852
102PF	59,015	88,683		29,668
103PF	98,143	146,775		48,632
104PF	44,902	67,259		22,357
105PF	29,507	44,290		14,783
106PF	91,088	137,608		46,520
107PF	59,015	88,683		29,668
108PF	53,241	79,516		26,275

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
109PF	42,337	64,169		21,832
110PF	103,265	17,613	85,652	
111PF	171,779	624,592		452,813
112PF	82,699	19,261	63,438	
113PF	36,940	157,384		120,444
114PF	408,968	315,180	93,788	
115PF	164,490	99,704	64,786	
116PF	269,293	374,920		105,627
117PF	296,831	156,560	140,271	
118PF	602,790	107,120	495,670	
119PF	329,251	64,787	264,464	
120PF	392,434	350,200	42,234	
121PF	548,049	73,130	474,919	
122PF	437,372	34,814	402,558	
123PF	141,110	76,323	64,787	
124PF	320,192	19,879	300,313	
125PF	317,265	279,130	38,135	
126PF	448,752	375,950	72,802	
127PF	447,675	23,278	424,397	
128PF	539,759	26,574	513,185	
129PF	584,367	58,092	526,275	
130PF	528,429	74,675	453,754	

TABLE 2--Continued

District	FP_i	FCM_i	Surplus	Deficit
131PF	301,633	132,767	168,866	
132PF	387,953	134,518	253,435	
133PF	116,716	56,444	60,272	
134PF	228,024	66,435	161,589	
135PF	74,698	18,231	56,467	
136PF	69,070	43,157	25,913	
137PF	444,284	398,610	45,674	
138PF	4,483	824	3,659	
139PF	22,250	4,944	17,306	
140PF	284,916	117,420	167,496	
141PF	204,824	14,935	189,889	
142PF	43,039	1,339	41,700	
143PF	15,458	618	14,840	
144PF	15,307	824	14,483	
145PF	16,479	824	15,655	
146PF	940	-0-	940	
147PF	9,951	515	9,436	
148PF	107,338	41,509	65,829	
Totals	25,896,260	25,896,260	10,664,724	10,664,724

in the Panhandle and High Plains area of Texas, Nebraska, Kansas, and Colorado. These states accounted for 72.0 percent of the total deficit of feeder cattle.

Table 3 contains fed cattle marketed, fed cattle slaughtered, and surplus or deficit by slaughter-consumption districts. Of the 89 slaughter-consumption districts, 37 showed surpluses and 52 showed deficits. Total surplus and total deficit were both equal to 9,316,608 thousand pounds.

Most of the surplus of fed cattle marketed was concentrated in the Panhandle and the north-central area of Texas, Nebraska, and Kansas. These states accounted for 57.2 percent of the total surplus of fed cattle. Most of the deficit of fed cattle was concentrated in the eastern and southwestern areas of Texas, Nebraska, and Wisconsin. These states accounted for 31.7 percent of the total deficit of feeder cattle.

Table 4 contains non-fed cattle marketed, non-fed cattle slaughtered, and surplus or deficit by slaughter-consumption districts. Of the 89 slaughter-consumption districts, 53 showed surpluses and 36 showed deficits. Total surplus and total deficit were both equal to 6,624,758 thousand pounds.

Most of the surplus of non-fed cattle marketed was concentrated in the eastern and southern areas of Texas, Oklahoma, Montana, Kentucky, and Alabama. These states accounted for 34.8 percent of the total surplus of non-fed cattle

TABLE 3.--Fed Cattle Marketed, Fed Cattle Slaughtered, and Surplus or Deficit, by Slaughter-Consumption Districts, 1976, 48 States

District	Fed Cattle Marketed (FCM_i)	Fed Cattle Slaughtered (FCS_i)	Surplus	Deficit
1SC	2,583,549	1,620,302	963,247	
2SC	365,032	111,057	253,975	
3SC	360,706	150,742	209,964	
4SC	32,445	304,167		271,722
5SC	12,978	222,423		209,445
6SC	306,734	141,509	165,225	
7SC	151,204	470,618		319,414
8SC	252,762	168,532	84,230	
9SC	618,000	791,977		173,977
10SC	758,801	990,133		231,332
11SC	858,505	589,460	269,045	
12SC	756,844	485,454	271,390	
13SC	1,030,103	162,534	867,569	
14SC	620,060	745,240		125,180
15SC	509,953	342,558	167,395	
16SC	499,653	1,663,526		1,163,873
17SC	561,144	79,307	481,837	
18SC	340,827	19,858	320,969	
19SC	1,178,217	220,840	957,377	
20SC	1,884,591	1,029,944	854,647	

TABLE 3--Continued

District	FCM_i	FCS_i	Surplus	Deficit
21SC	113,712	604,703		490,991
22SC	49,337	305,533		256,196
23SC	41,097	25,693	15,404	
24SC	28,840	22,122	6,718	
25SC	42,539	15,907	26,632	
26SC	68,495	31,367	37,128	
27SC	26,059	87,704		61,645
28SC	45,217	42,372	2,845	
29SC	45,217	9,001	36,216	
30SC	9,579	19,778		10,199
31SC	698,340	469,783	228,557	
32SC	158,208	10,088	148,120	
33SC	282,941	189,874	93,067	
34SC	170,156	140,415	29,741	
35SC	846,866	460,652	386,214	
36SC	441,149	882,854		441,705
37SC	117,214	725,557		608,343
38SC	70,246	324,683		254,437
39SC	107,738	15,761	91,977	
40SC	119,480	16,853	102,627	
41SC	179,117	263,322		84,205
42SC	59,740	209,663		149,923

TABLE 3--Continued

District	FCM_i	FCS_i	Surplus	Deficit
43SC	134,827	196,857		62,030
44SC	80,855	189,127		108,272
45SC	146,363	95,184	51,179	
46SC	596,370	501,717		94,653
47SC	-0-	1,103		1,103
48SC	1,515,954	730,067	785,887	
49SC	291,284	523,726		232,442
50SC	35,844	15,956	19,888	
51SC	365,238	115,538	249,700	
52SC	334,750	718,129		383,379
53SC	628,300	209,940	418,360	
54SC	818,850	325,346	493,504	
55SC	315,180	295,113	20,067	
56SC	99,704	205,192		105,488
57SC	374,920	494,675		119,755
58SC	156,560	145,138	11,422	
59SC	107,120	86,974	20,146	
60SC	64,787	27,314	37,473	
61SC	350,200	368,424		18,224
62SC	73,130	167,039		93,909
63SC	34,814	147,431		112,617
64SC	76,323	162,019		85,696

TABLE 3--Continued

District	FCM_i	FCS_i	Surplus	Deficit
65SC	19,879	97,132		77,253
66SC	279,130	589,691		310,561
67SC	375,950	366,511	9,439	
68SC	23,278	223,724		200,446
69SC	26,574	401,715		375,141
70SC	58,092	214,463		156,371
71SC	74,675	182,888		108,213
72SC	132,767	293,705		160,938
73SC	134,518	365,942		231,424
74SC	56,444	70,993		14,549
75SC	66,435	128,779		62,344
76SC	18,231	58,223		39,992
77SC	43,157	69,509		26,352
78SC	398,610	804,445		405,835
79SC	824	3,848		3,024
80SC	4,944	170,933		165,989
81SC	117,420	619,225		501,805
82SC	14,935	208,037		193,102
83SC	1,339	16,286		14,947
84SC	618	29,019		28,401
85SC	824	12,364		11,540

TABLE 3--Continued

District	FCM_i	FCS_i	Surplus	Deficit
86SC	824	22,780		21,956
87SC	-0-	7,140		7,140
88SC	515	24,298		23,783
89SC	41,509	8,735		32,774
Totals	25,896,260	25,896,260	9,316,608	9,316,608

TABLE 4.--Non-Fed Cattle Marketed, Non-Fed Cattle Slaughtered, and Surplus or Deficit, by Slaughter-Consumption Districts, 1976, 48 States

District	Non-Fed Cattle Marketed ($NFCM_i$)	Non-Fed Cattle Slaughtered ($NFCS_i$)	Surplus	Deficit
1SC	304,455	1,224,876		920,421
2SC	69,355	79,763		10,408
3SC	332,033	87,707	244,326	
4SC	279,880	210,689	69,191	
5SC	360,431	140,604	219,827	
6SC	209,568	91,162	118,406	
7SC	375,449	330,962	44,487	
8SC	198,646	112,972	85,674	
9SC	255,393	597,064		341,671
10SC	313,557	746,777		433,220
11SC	354,255	435,070		80,815
12SC	321,569	357,123		44,554
13SC	343,001	125,507	217,494	
14SC	206,162	575,469		369,307
15SC	169,419	264,521		95,102
16SC	166,522	1,284,564		1,118,042
17SC	186,614	61,240	125,374	
18SC	113,851	15,335	98,516	
19SC	418,558	128,308	290,250	
20SC	468,623	748,044		279,421

TABLE 4--Continued

District	$NFCM_i$	$NFCS_i$	Surplus	Deficit
21SC	211,912	445,571		233,659
22SC	120,321	232,299		111,978
23SC	99,166	16,847	82,319	
24SC	70,738	14,948	55,790	
25SC	102,471	9,190	93,281	
26SC	169,243	19,113	150,130	
27SC	62,805	65,829		3,024
28SC	112,388	29,327	83,061	
29SC	111,727	3,577	108,150	
30SC	23,799	14,555	9,244	
31SC	873,424	258,619	614,805	
32SC	64,223	7,789	56,434	
33SC	115,154	146,620		31,466
34SC	69,170	108,427		39,257
35SC	344,381	355,713		11,332
36SC	179,919	681,735		501,816
37SC	267,215	459,328		192,113
38SC	160,291	190,166		29,875
39SC	84,161	2,457	81,704	
40SC	94,298	2,097	92,201	
41SC	139,716	187,148		47,432
42SC	46,533	156,480		109,947

TABLE 4--Continued

District	$NFCM_i$	$NFCS_i$	Surplus	Deficit
43SC	106,254	139,663		33,409
44SC	63,946	138,664		74,718
45SC	114,968	60,174	54,794	
46SC	719,368	362,906	356,462	
47SC	57,891	851	57,040	
48SC	239,691	563,754		324,063
49SC	149,299	404,418		255,119
50SC	97,502	12,322	85,180	
51SC	115,783	89,218	26,565	
52SC	150,744	505,141		354,397
53SC	282,427	69,570	212,857	
54SC	266,523	175,006	91,517	
55SC	276,170	227,885	48,285	
56SC	111,077	97,140	13,937	
57SC	181,850	227,823		45,973
58SC	200,446	112,075	88,371	
59SC	407,055	67,161	339,894	
60SC	222,339	8,400	213,939	
61SC	265,005	254,184	10,821	
62SC	370,089	124,408	245,681	
63SC	295,351	66,819	228,532	
64SC	95,290	39,733	55,557	

TABLE 4--Continued

District	$NFCM_i$	$NFCS_i$	Surplus	Deficit
65SC	216,221	52,994	163,227	
66SC	214,244	237,096		22,852
67SC	303,036	144,015	159,021	
68SC	302,309	172,759	129,550	
69SC	364,492	288,389	76,103	
70SC	394,615	127,151	267,464	
71SC	356,840	58,064	298,776	
72SC	203,689	145,231	58,458	
73SC	261,979	165,347	96,632	
74SC	78,817	27,666	51,151	
75SC	153,982	66,218	87,764	
76SC	50,443	954	49,489	
77SC	46,642	22,549	24,093	
78SC	300,019	354,729		54,710
79SC	3,028	952	2,076	
80SC	15,025	131,994		116,969
81SC	192,399	478,161		285,762
82SC	138,315	160,644		22,329
83SC	29,064	6,791	22,273	
84SC	10,439	20,330		9,891
85SC	10,336	7,490	2,846	
86SC	11,128	15,375		4,247

TABLE 4--Continued

District	$NFCM_i$	$NFCS_i$	Surplus	Deficit
87SC	634	5,386		4,752
88SC	6,719	17,426		10,707
89SC	72,484	6,745	65,739	
Totals	17,487,363	17,487,363	6,624,758	6,624,758

marketed. Most of the deficit of non-fed cattle marketed was concentrated in the Panhandle and High Plains areas of Texas, Iowa, and Nebraska. These states accounted for 51.5 percent of the total deficit of non-fed cattle marketed.

Table 5 contains total cattle slaughtered, beef consumption, and surplus or deficit by slaughter-consumption districts. Of the 89 slaughter-consumption districts, 38 showed surpluses and 51 showed deficits. Total surplus and total deficits were both equal to 21,566,159 thousand pounds.

Most of the surplus of cattle slaughtered was concentrated in the Panhandle of Texas, Iowa, Nebraska, Kansas, and Colorado. These states accounted for 79.9 percent of the total slaughter surplus. Most of the deficit of cattle slaughtered was concentrated in California, Illinois, Michigan, Ohio, New Jersey, Pennsylvania, New York, and Massachusetts. These states accounted for 58.3 percent of the total slaughter deficit.

Feeder Cattle Shipments

Table 6 contains optimal shipments of feeder cattle among districts under the combination of interstate transportation rates, which are a function of distance, and the 1976 intrastate transportation rates whenever applicable. As shown in Table 6, the majority of the Texas feeder cattle surplus was shipped interstate to Kansas (35PF) and Arizona (111PF, 113PF). Only 20 percent of the surplus in the state

TABLE 5.--Total Cattle Slaughtered, Beef Consumption, and Surplus or Deficit, by Slaughter-Consumption Districts, 1976, 48 States

District	Cattle Slaughtered $(NFCS_i+FCS_i)$	Beef Consumption (AC_i)	Surplus	Deficit
1SC	2,845,178	73,038	2,772,140	
2SC	190,820	88,825	101,995	
3SC	238,449	128,038	110,411	
4SC	514,856	640,624		125,768
5SC	363,027	235,226	127,801	
6SC	232,671	174,272	58,399	
7SC	801,580	963,590		162,010
8SC	281,504	134,847	146,657	
9SC	1,389,041	90,733	1,298,308	
10SC	1,736,910	99,972	1,636,938	
11SC	1,024,530	232,190	792,340	
12SC	842,577	222,365	620,212	
13SC	288,041	30,852	257,189	
14SC	1,320,709	32,362	1,288,347	
15SC	607,079	29,751	577,328	
16SC	2,948,090	194,595	2,753,495	
17SC	140,547	33,073	107,474	
18SC	35,193	27,561	7,632	
19SC	349,148	82,990	266,158	
20SC	1,777,988	203,947	1,574,041	

TABLE 5--Continued

District	Cattle Slaughtered	Beef Consumption	Surplus	Deficit
21SC	1,050,274	227,320	822,954	
22SC	537,832	88,245	449,587	
23SC	42,540	34,042	8,498	
24SC	37,070	28,615	8,455	
25SC	25,097	184,833		159,736
26SC	50,480	105,653		55,173
27SC	153,533	438,590		285,057
28SC	71,699	90,865		19,166
29SC	12,578	47,585		35,007
30SC	34,333	57,459		23,126
31SC	728,402	539,932	188,470	
32SC	17,877	80,260		62,383
33SC	336,494	1,173,553		837,059
34SC	248,842	279,892		31,050
35SC	816,365	456,518	359,847	
36SC	1,564,589	2,749,165		1,184,576
37SC	1,184,885	445,482	739,403	
38SC	514,849	586,988		72,139
39SC	18,218	121,967		103,749
40SC	18,950	40,825		21,875
41SC	450,470	102,704	347,766	
42SC	366,143	413,317		47,174

TABLE 5--*Continued*

District	Cattle Slaughtered	Beef Consumption	Surplus	Deficit
43SC	336,520	31,901	304,619	
44SC	327,791	70,446	257,345	
45SC	155,358	102,165	53,193	
46SC	864,623	154,000	710,623	
47SC	1,954	22,811		20,857
48SC	1,293,821	167,381	1,126,440	
49SC	928,144	280,434	647,710	
50SC	28,278	46,111		17,833
51SC	204,756	51,317	153,439	
52SC	1,223,270	1,802,833		579,563
53SC	279,510	724,894		445,384
54SC	500,352	497,372	2,980	
55SC	522,998	255,678	267,320	
56SC	302,332	268,832	33,500	
57SC	722,498	794,251		71,753
58SC	257,213	510,614		253,401
59SC	154,135	166,806		12,671
60SC	35,714	84,116		48,402
61SC	622,608	181,899	440,709	
62SC	291,447	145,011	146,436	
63SC	214,250	368,181		153,931
64SC	201,752	950,929		749,177

TABLE 5--Continued

District	Cattle Slaughtered	Beef Consumption	Surplus	Deficit
65SC	150,126	664,773		514,647
66SC	826,787	2,056,374		1,229,587
67SC	510,526	1,197,548		687,022
68SC	396,483	409,390		12,907
69SC	690,104	729,461		39,357
70SC	341,614	592,059		250,445
71SC	240,952	631,913		390,961
72SC	438,936	861,751		422,815
73SC	531,289	1,447,542		916,253
74SC	98,659	492,122		393,463
75SC	194,997	870,399		675,402
76SC	59,177	314,452		255,275
77SC	92,058	720,287		628,229
78SC	1,159,174	2,421,463		1,262,289
79SC	4,800	101,256		96,456
80SC	302,927	1,490,119		1,187,192
81SC	1,097,386	2,410,805		1,313,419
82SC	368,681	3,673,088		3,304,407
83SC	23,077	95,930		72,853
84SC	49,349	1,181,145		1,131,796
85SC	19,854	629,983		610,129

TABLE 5--*Continued*

District	Cattle Slaughtered	Beef Consumption	Surplus	Deficit
86SC	38,155	214,985		176,830
87SC	12,526	189,230		176,704
88SC	41,724	164,964		123,240
89SC	15,480	131,941		116,461
Totals	43,383,623	43,383,623	21,566,159	21,566,159

TABLE 6.--Optimal Feeder Cattle Shipments, Using Combination of Interstate and Intrastate Rates, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Childress (3PF)	Amarillo (1PF)	42,511
Graham (5PF)	Liberal (35PF)	191,955
Dallas (6PF)	Liberal	382,016
Tyler (7PF)	Liberal	354,696
	Pueblo (100PF)	852
Huntsville (8PF)	Ft. Stockton (9PF)	150,380
	Liberal (35PF)	14,840
San Angelo (10PF)	Lubbock (2PF)	153,987
San Antonio (11PF)	Phoenix (111PF)	122,308
	Yuma (113PF)	120,444
Corpus Christi (12PF)	McAllen (15PF)	982
	Phoenix (111PF)	9,454
Houston (13PF)	Pueblo (100PF)	86,954
	Phoenix (111PF)	64,537
Laredo (14PF)	Phoenix	42,491
KANSAS:		
Concordia (36PF)	Greeley (96PF)	46,221
Atchison (39PF)	Holdredge (31PF)	67,289
	Greeley (96PF)	23,100
Topeka (40PF)	Greeley	109,685
Independence (41PF)	Pueblo (100PF)	71,119

TABLE 6--Continued

From	To	Amount
MISSOURI:		
St. Joseph (42PF)	Holdredge (31PF)	63,264
	St. Francis (33PF)	65,577
Kirksville (43PF)	Grand Island (28PF)	105,753
Hannibal (44PF)	North Platte (30PF)	24,797
	Beatrice (32PF)	51,116
Kansas City (45PF)	Salina (37PF)	109,206
Jefferson City (46PF)	Tribune (34PF)	182,129
St. Louis (47PF)	Beatrice (32PF)	66,946
Joplin (48PF)	Tribune (34PF)	121,213
West Plains (49PF)	Tribune	104,519
	Wichita (38PF)	15,715
Sikeston (50PF)	Tribune (34PF)	18,277
	Pueblo (100PF)	7,388
OKLAHOMA:		
Guymon (51PF)	Liberal (35PF)	57,110
Clinton (52PF)	Amarillo (1PF)	49,110
Lawton (53PF)	Amarillo	53,566
Enid (54PF)	Liberal (35PF)	62,933
Oklahoma City (55PF)	Amarillo (1PF)	98,874
Ardmore (56PF)	Amarillo	84,196
Tulsa (57PF)	Liberal (35PF)	95,227

TABLE 6--Continued

From	To	Amount
Muskogee (58PF)	Liberal (35PF)	60,399
Hugo (59PF)	Amarillo (1PF)	33,662
WISCONSIN:		
Hayward (68PF)	Spencer (16PF)	12,086
	Norfolk (27PF)	32,047
Rhinelander (69PF)	Spencer (16PF)	42,185
Marinette (70PF)	Decorah (18PF)	21,346
Eau Claire (71PF)	Spencer (16PF)	72,958
Wisconsin Rapids (72PF)	Decorah (18PF)	31,835
Oshkosh (73PF)	Mason City (17PF)	45,391
	Decorah (18PF)	20,644
Prairie du Chien (74PF)	Decorah	80,108
Madison (75PF)	Cedar Rapids (21PF)	66,732
Milwaukee (76PF)	Spencer (16PF)	20,283
MINNESOTA:		
Crookston (77PF)	Valentine (26PF)	13,449
Bemidji (78PF)	Norfolk (27PF)	3,106
Hibbing (79PF)	Norfolk	338
Fergus Falls (80PF)	Norfolk	20,162
St. Cloud (81PF)	Norfolk	27,782
Minneapolis (82PF)	Spencer (16PF)	9,168
Worthington (83PF)	Norfolk (27PF)	22,520
Mankato (84PF)	Spencer (16PF)	13,840

TABLE 6--Continued

From	To	Amount
Rochester (85PF)	Spencer (16PF)	2,330
	Mason City (17PF)	21,558
SOUTH DAKOTA:		
Bison (86PF)	Scottsbluff (25PF)	39,281
Aberdeen (87PF)	Valentine (26PF)	66,532
Watertown (88PF)	Norfolk (27PF)	51,414
Rapid City (89PF)	Scottsbluff (25PF)	37,123
Huron (90PF)	Valentine (26PF)	66,532
Sioux Falls (91PF)	Norfolk (27PF)	72,598
Hot Springs (92PF)	Scottsbluff (25PF)	22,622
Winner (93PF)	Valentine (26PF)	47,715
Yankton (94PF)	Norfolk (27PF)	65,093
COLORADO:		
Craig (95PF)	Greeley (96PF)	15,536
	Denver (97PF)	70,193
Grand Junction (98PF)	Los Angeles (67PF)	81,075
Alamosa (99PF)	Pueblo (100PF)	27,467
ARIZONA:		
Flagstaff (110PF)	Los Angeles (67PF)	28,855
	Phoenix (111PF)	56,797
Tucson (112PF)	Phoenix	63,438
OTHER STATES:		
Albuquerque (114PF)	Phoenix	93,788

TABLE 6--Continued

From	To	Amount
Salt Lake City (115PF)	Los Angeles (67PF)	64,786
Bend (117PF)	Eureka (60PF)	16,217
	Redding (61PF)	22,224
	San Jose (63PF)	101,830
Great Falls (118PF)	Alturas (62PF)	24,662
	San Jose (63PF)	10,584
	Fresno (65PF)	296,551
	Greeley (96PF)	58,246
	Seattle (116PF)	105,627
Casper (119PF)	Greeley (96PF)	264,464
Boise (120PF)	Sacramento (64PF)	1,897
	Fresno (65PF)	12,322
	Bridgeport (66PF)	28,015
Bismark (121PF)	Scottsbluff (25PF)	99,467
	Valentine (26PF)	129,447
	Greeley (96PF)	246,005
Little Rock (122PF)	Amarillo (1PF)	381,829
	Liberal (35PF)	20,729
Raleigh (123PF)	Red Oak (22PF)	64,787
Baton Rouge (124PF)	Amarillo (1PF)	300,313
Lansing (125PF)	Dixon (101PF)	8,467
	Chicago (102PF)	29,668

TABLE 6--Continued

From	To	Amount
Indianapolis (126PF)	Red Oak (22PF)	14,748
	Burlington (24PF)	41,322
	Bloomington (104PF)	1,949
	Champaign (105PF)	14,783
Jackson (127PF)	Amarillo (1PF)	424,397
Nashville (128PF)	North Platte (30PF)	85,469
	Salina (37PF)	3,692
	Greeley (96PF)	397,749
	Chester (108PF)	26,275
Lexington (129PF)	Denison (19PF)	171,864
	Osceola (23PF)	10,467
	Grand Island (28PF)	153,316
	North Platte (30PF)	43,976
	Quincy (103PF)	48,632
	Springfield (106PF)	46,520
	Effingham (107PF)	29,668
	Mt. Vernon (109PF)	21,832
Montgomery (130PF)	Amarillo (1PF)	345,415
	Lubbock (2PF)	108,339
Atlanta (131PF)	Amarillo (1PF)	168,866
Orlando (132PF)	Amarillo	149,957
	Abilene (4PF)	103,478

TABLE 6--Continued

From	To	Amount
Columbia (133PF)	Beatrice (32PF)	54,169
	Wichita (38PF)	6,103
Richmond (134PF)	Red Oak (22PF)	43,068
	Osceola (23PF)	118,521
Charleston (135PF)	Burlington (24PF)	56,467
Baltimore (136PF)	Omaha (29PF)	25,913
Columbus (137PF)	Omaha	25,266
	Bloomington (104PF)	20,408
Dover (138PF)	Omaha (29PF)	3,659
Trenton (139PF)	Des Moines (20PF)	17,306
Harrisburg (140PF)	Des Moines	73,226
	Omaha (29PF)	94,270
Syracuse (141PF)	Cedar Rapids (21PF)	73,311
	Norfolk (27PF)	19,703
	Omaha (29PF)	23,490
	Dixon (101PF)	73,385
Montpelier (142PF)	Omaha (29PF)	41,700
Boston (143PF)	Omaha	14,840
Hartford (144PF)	Omaha	14,483
Augusta (145PF)	Des Moines (20PF)	15,655
Providence (146PF)	Des Moines	940

TABLE 6--Continued

From	To	Amount
Concord (147PF)	Omaha (29PF)	9,436
Winnemucca (148PF)	Sacramento (64PF)	65,829

Total Cost - $149,180,703

Total Shipments - 10,664,724,000 pounds (livewt.)

Total Diesel Consumption - 34,497,446 gallons

Total Distance Traveled - 146,614,145 miles

was shipped to destinations within the state (1PF, 9PF, 2PF, 15PF). Of the deficit of Texas feeder cattle, 86.9 percent was supplied by interstate shipments from surplus districts in Oklahoma (52PF, 53PF, 55PF, 56PF, 59PF), Arkansas (122PF), Louisiana (124PF), Mississippi (127PF), Alabama (130PF), Georgia (131PF), and Florida (132PF). Even though the Texas deficit of feeder cattle was approximately 2.6 billion pounds, only 347.9 million pounds of the Texas surplus was shipped to destinations within Texas.

Since Iowa had no surplus feeder cattle, the Iowa deficit was supplied by shipments from other states. Wisconsin (68PF-76PF), Minnesota (82PF, 84PF, 85PF), North Carolina (123PF), Indiana (126PF), and Kentucky (129PF) were the major suppliers of Iowa.

None of the Kansas feeder cattle surplus was shipped to destinations within Kansas; 21.2 percent of the surplus was shipped to Nebraska (31PF), and 78.8 percent was shipped to Colorado destinations (96PF, 100PF). Texas (5PF-8PF), Missouri (42PF, 45PF, 46PF, 48PF-50PF) and Oklahoma (51PF, 54PF, 57PF, 58PF) supplied 98.4 percent of the Kansas deficit.

California had no surplus feeder cattle. Therefore, California districts received shipments of feeder cattle from other states. Colorado (98PF), Arizona (110PF), Utah (115PF), Oregon (117PF), Montana (118PF), Idaho (120PF), and Nevada (148PF) shipped feeder cattle to California.

South Dakota surplus regions (86PF-94PF) shipped feeder cattle to deficit regions in Nebraska (25PF-27PF). The shipments from South Dakota to Nebraska supplied approximately 26 percent of the Nebraska deficit. South Dakota had no deficit of feeder cattle.

Of the Colorado feeder cattle surplus, 58.3 percent was shipped to deficit districts (96PF, 97PF, 100PF) within Colorado. The remainder of the Colorado surplus was shipped to California (67PF). Only 7.9 percent of the Colorado deficit was supplied by shipments from Colorado surplus districts. Texas (7PF, 13PF), Kansas (36PF, 39PF, 40PF, 41PF), Missouri (50PF), Montana (118PF), Wyoming (119PF), North Dakota (121PF), and Tennessee (128PF) supplied the remainder of the Colorado deficit.

Illinois had no surplus of feeder cattle. Therefore, Illinois districts (101PF-109PF) received shipments of feeder cattle from other states. Michigan (125PF), Indiana (126PF), Tennessee (128PF), Kentucky (129PF), Ohio (137PF), and New York (141PF) supplied the Illinois deficit.

The Arizona feeder cattle deficit was approximately 3.8 times larger than the state's surplus of feeder cattle. Of the Arizona surplus, 80.6 percent was shipped to destinations within Arizona. The remainder of the surplus feeder cattle in Arizona were shipped to California (67PF). Texas (11PF-13PF), and New Mexico (114PF) were the other states that supplied the Arizona deficit.

Regulated rates were not obtained for the remainder of the states included in the optimal solution presented in Table 6. Therefore, the optimal shipments for these states will not be discussed.

The optimal solution of transporting feeder cattle among 148 districts in the 48 states for the model which used available intrastate and interstate rates effective in 1976 involved:

(1) a total cost of $149.2 million;

(2) 10,664.7 million pounds liveweight;

(3) 34.5 million gallons of diesel;

(4) 146.6 million miles.

Table 7 contains optimal shipments of feeder cattle among districts under the system of transportation costs which were estimated as a function of distance. As shown in Table 7, approximately 81 percent of the Texas feeder cattle surplus was shipped to destinations within the state. The remainder was shipped to destinations in Arizona (111PF, 113PF). Of the deficit of Texas feeder cattle, 53.1 percent was supplied by shipments from districts within the state. Shipments of feeder cattle from Oklahoma (53PF, 56PF), Louisiana (124PF), Mississippi (127PF), Alabama (130PF), and Florida (132PF) supplied the remainder of the Texas deficit.

The Iowa deficit of feeder cattle was supplied by approximately the same states as shown in Table 6. The only

TABLE 7.--Optimal Feeder Cattle Shipments, Using Estimated Shipping Costs, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Childress (3PF)	Amarillo (1PF)	42,511
Graham (5PF)	Amarillo	49,045
	Lubbock (2PF)	142,910
Dallas (6PF)	Amarillo (1PF)	382,016
Tyler (7PF)	Amarillo	355,548
Huntsville (8PF)	Amarillo	165,220
San Angelo (10PF)	Ft. Stockton (9PF)	118,305
	Phoenix (111PF)	35,682
San Antonio (11PF)	Phoenix	185,746
	Yuma (113PF)	57,006
Corpus Christi (12PF)	McAllen (15PF)	982
	Phoenix (111PF)	9,454
Houston (13PF)	Lubbock (2PF)	119,416
	Ft. Stockton (9PF)	32,075
Laredo (14PF)	Phoenix (111PF)	42,491
KANSAS:		
Concordia (36PF)	Greeley (96PF)	46,221
Atchison (39PF)	Greeley	90,389
Topeka (40PF)	Salina (37PF)	109,685
Independence (41PF)	Wichita (38PF)	21,818
	Pueblo (100PF)	49,301

TABLE 7--Continued

From	To	Amount
MISSOURI:		
St. Joseph (42PF)	Greeley (96PF)	128,841
Kirksville (43PF)	Grand Island (28PF)	61,777
	North Platte (30PF)	43,976
Hannibal (44PF)	Beatrice (32PF)	75,913
Kansas City (45PF)	St. Francis (33PF)	65,577
	Salina (37PF)	3,213
	Greeley (96PF)	40,416
Jefferson City (46PF)	Tribune (34PF)	159,377
	Greeley (96PF)	22,752
St. Louis (47PF)	Greeley	66,946
Joplin (48PF)	Tribune (34PF)	121,213
West Plains (49PF)	Tribune	3,222
	Pueblo (100PF)	117,012
Sikeston (50PF)	Tribune (34PF)	25,665
OKLAHOMA:		
Guymon (51PF)	Liberal (35PF)	57,110
Clinton (52PF)	Liberal	49,110
Lawton (53PF)	Amarillo (1PF)	53,566
Enid (54PF)	Liberal (35PF)	62,933
Oklahoma City (55PF)	Liberal	98,874
Ardmore (56PF)	Amarillo (1PF)	84,196

TABLE 7--Continued

From	To	Amount
Tulsa (57PF)	Liberal (35PF)	95,227
Muskogee (58PF)	Liberal	60,399
Hugo (59PF)	Liberal	33,662
WISCONSIN:		
Hayward (68PF)	Spencer (16PF)	12,086
	Norfolk (27PF)	32,047
Rhinelander (69PF)	Spencer (16PF)	42,185
Marinette (70PF)	Mason City (17PF)	21,346
Eau Claire (71PF)	Spencer (16PF)	72,958
Wisconsin Rapids (72PF)	Mason City (17PF)	24,045
	Decorah (18PF)	7,790
Oshkosh (73PF)	Decorah	66,035
Prairie du Chien (74PF)	Decorah	80,108
Madison (75PF)	Cedar Rapids (21PF)	66,732
Milwaukee (76PF)	Spencer (16PF)	20,283
MINNESOTA:		
Crookston (77PF)	Valentine (26PF)	13,449
Bemidji (78PF)	Norfolk (27PF)	3,106
Hibbing (79PF)	Norfolk	338
Fergus Falls (80PF)	Norfolk	20,162
St. Cloud (81PF)	Norfolk	27,782
Minneapolis (82PF)	Spencer (16PF)	9,168
Worthington (83PF)	Norfolk (27PF)	22,520

TABLE 7--Continued

From	To	Amount
Mankato (84PF)	Spencer (16PF)	13,840
Rochester (85PF)	Spencer	2,330
	Mason City (17PF)	21,558
SOUTH DAKOTA:		
Bison (86PF)	Scottsbluff (25PF)	39,281
Aberdeen (87PF)	Valentine (26PF)	66,532
Watertown (88PF)	Norfolk (27PF)	51,414
Rapid City (89PF)	Scottsbluff (25PF)	37,123
Huron (90PF)	Valentine (26PF)	66,532
Sioux Falls (91PF)	Norfolk (27PF)	72,598
Hot Springs (92PF)	Scottsbluff (25PF)	22,622
Winner (93PF)	Valentine (26PF)	47,715
Yankton (94PF)	Norfolk (27PF)	65,093
COLORADO:		
Craig (95PF)	Greeley (96PF)	15,536
	Denver (97PF)	70,193
Grand Junction (98PF)	Los Angeles (67PF)	81,075
Alamosa (99PF)	Pueblo (100PF)	27,467
ARIZONA:		
Flagstaff (110PF)	Phoenix (111PF)	85,652
Tucson (112PF)	Yuma (113PF)	63,438
OTHER STATES:		
Albuquerque (114PF)	Phoenix (111PF)	93,788

TABLE 7--Continued

From	To	Amount
Salt Lake City (115PF)	Los Angeles (67PF)	64,786
Bend (117PF)	Eureka (60PF)	16,217
	Redding (61PF)	22,224
	San Jose (63PF)	101,830
Great Falls (118PF)	Alturas (62PF)	24,662
	San Jose (63PF)	10,584
	Fresno (65PF)	296,551
	Los Angeles (67PF)	28,855
	Greeley (96PF)	29,391
	Seattle (116PF)	105,627
Casper (119PF)	Greeley (96PF)	264,464
Boise (120PF)	Sacramento (64PF)	1,897
	Fresno (65PF)	12,322
	Bridgeport (66PF)	28,015
Bismark (121PF)	Scottsbluff (25PF)	99,467
	Valentine (26PF)	129,447
	Greeley (96PF)	246,005
Little Rock (122PF)	Liberal (35PF)	402,558
Raleigh (123PF)	Burlington (24PF)	27,647
	Bloomington (104PF)	22,357
	Champaign (105PF)	14,783
Baton Rouge (124PF)	Amarillo (1PF)	300,313
Lansing (125PF)	Norfolk (27PF)	8,467

TABLE 7--Continued

From	To	Amount
Lansing (cont'd.)	Chicago (102PF)	29,668
Indianapolis (126PF)	Red Oak (22PF)	2,660
	Burlington (24PF)	70,142
Jackson (127PF)	Amarillo (1PF)	424,397
Nashville (128PF)	North Platte (30PF)	110,266
	Holdredge (31PF)	130,553
	Beatrice (32PF)	36,046
	Greeley (96PF)	210,045
	Chester (108PF)	26,275
Lexington (129PF)	Denison (19PF)	171,864
	Osceola (23PF)	10,467
	Grand Island (28PF)	197,292
	Quincy (103PF)	48,632
	Springfield (106PF)	46,520
	Effingham (107PF)	29,668
	Mt. Vernon (109PF)	21,832
Montgomery (130PF)	Amarillo (1PF)	125,927
	Liberal (35PF)	327,827
Atlanta (131PF)	Tribune (34PF)	116,661
	Liberal (35PF)	52,205
Orlando (132PF)	Amarillo (1PF)	149,957
	Abilene (4PF)	103,478
Columbia (133PF)	Beatrice (32PF)	60,272

TABLE 7--Continued

From	To	Amount
Richmond (134PF)	Red Oak (22PF)	43,068
	Osceola (23PF)	118,521
Charleston (135PF)	Red Oak (22PF)	56,467
Baltimore (136PF)	Omaha (29PF)	25,913
Columbus (137PF)	Red Oak (22PF)	20,408
	Omaha (29PF)	25,266
Dover (138PF)	Omaha	3,659
Trenton (139PF)	Omaha	17,306
Harrisburg (140PF)	Omaha	167,496
Syracuse (141PF)	Des Moines (20PF)	91,472
	Cedar Rapids (21PF)	73,311
	Omaha (29PF)	3,981
	Dixon (101PF)	21,125
Montpelier (142PF)	Dixon	41,700
Boston (143PF)	Dixon	14,840
Hartford (144PF)	Norfolk (27PF)	11,236
	Dixon (101PF)	3,247
Augusta (145PF)	Des Moines (20PF)	15,655
Providence (146PF)	Dixon (101PF)	940
Concord (147PF)	Omaha (29PF)	9,436

TABLE 7--Continued

From	To	Amount
Winnemucca (148PF)	Sacramento (64PF)	65,829

Total Cost - $146,666,282

Total Shipments - 10,664,724,000 pounds (livewt.)

Total Diesel Consumption - 34,025,497 gallons

Total Distance Traveled - 144,608,364 miles

changes were that New Jersey (139PF), Pennsylvania (140PF), and Rhode Island (146PF) shipped cattle to Iowa, and Ohio (137PF) did not ship to Iowa.

Of the Kansas surplus of feeder cattle, 41.4 percent was shipped to destinations within Kansas. The remainder was shipped to Colorado (96PF, 100PF). Only 7.05 percent of the Kansas deficit of feeder cattle was supplied by shipments from districts within the state. The remainder of the Kansas deficit was supplied by Missouri (45PF, 46PF, 48PF, 50PF), Oklahoma (51PF, 52PF, 54PF, 55PF, 57PF-59PF), Arkansas (122PF), Alabama (130PF), and Georgia (131PF).

The deficit of feeder cattle in California was supplied by shipments of cattle from Colorado (98PF); Utah (115PF), Oregon (117PF), Montana (118PF), Idaho (120PF), and Nevada (148PF). In this optimal solution Arizona did not ship to California. As shown in Table 7, all Arizona shipments of feeder cattle were to destinations within Arizona.

South Dakota surplus regions (86PF-94PF) shipped to the same Nebraska deficit regions in this optimal solution as shown in Table 6. Of the surplus, 21.1 percent was shipped to Scottsbluff (25PF), 38.6 percent was shipped to Valentine (26PF), and 40.3 percent went to Norfolk (27PF).

Colorado surplus districts (95PF, 98PF, 99PF) maintained the same shipping activities in this optimal solution as those derived in the previous solution. From the Colorado surplus, 58.3 percent was shipped to destinations within the state, while the remainder was shipped to California (67PF). As in the previous optimal solution, 92.1 percent of the Colorado deficit was supplied by shipments from other states in this solution. Kansas (36PF, 39PF, 41PF), Missouri (42PF, 45PF-47PF, 49PF), Montana (118PF), Wyoming (119PF), North Dakota (121PF), and Tennessee (128PF) were the major suppliers of the Colorado deficit in this solution.

The deficit of feeder cattle in Illinois was supplied by different shipping activities than those presented in Table 6. North Carolina (123PF), Michigan (125PF), Tennessee (128PF), Kentucky (129PF), New York (141PF), Vermont (142PF), Massachusetts (143PF), Connecticut (144PF), and Rhode Island (146PF) were the major suppliers of the Illinois deficit.

All of the surplus of Arizona feeder cattle was shipped to destinations within the state. Flagstaff (110PF) supplied Phoenix (111PF), and Tucson (112PF) supplied Yuma (113PF). The Arizona deficit districts also received shipments of feeder cattle from Texas (10PF-12PF, 14PF) and New Mexico (114PF).

The optimal solution of transporting feeder cattle among 148 districts in the 48 states for the transportation model which used shipping costs estimated as a function of distance involved:

(1) a total cost of $146.7 million;

(2) 10,664.7 million pounds liveweight;

(3) 34.0 million gallons of diesel;

(4) 144.6 million miles.

It can be seen from Tables 6 and 7 that using shipping costs estimated as a function of distance resulted in an optimal solution with lower totals of cost, diesel consumption and miles traveled than the results that were obtained from the model which used the available 1976 shipping rates. Shipping costs were lower by 1.69 percent, and diesel consumption and distance traveled were both lower by 1.37 percent.

A comparison of Tables 6 and 7 shows the changes in shipping activities that resulted in the lower estimates stated above. Approximately 61 percent more of the surplus of Texas feeder cattle was shipped to destinations within the state in the model which utilized only estimated shipping costs than in the model which utilized available 1976 rates. Intrastate shipments of surplus Kansas feeder cattle increased from 0.0 percent to 41.4 percent. The deficit of feeder cattle in Illinois was supplied by more Northeastern states in the solution shown in Table 7 than the solution in Table 6. Intrastate shipments of surplus feeder cattle in Arizona increased from 80.6 percent to 100 percent.

Fed Cattle Shipments

Table 8 contains optimal shipments of fed cattle among districts under the combination of interstate transportation rates, which are a function of distance, and the 1976 intrastate transportation rates whenever applicable. As shown in Table 8, 77.4 percent of the Texas fed cattle surplus was shipped interstate to Kansas (21SC), Arkansas (63SC), Mississippi (68SC), Tennessee (69SC), Alabama (71SC), Georgia (72SC), Virginia (75SC), Florida (73SC), Delaware (79SC), and Louisiana (65SC). Only 22.6 percent of the Texas fed cattle surplus was shipped to destinations within the state (4SC, 5SC). Of the deficit of Texas fed cattle, 47.3 percent was supplied by shipments from surplus districts in the state (2SC, 3SC). The majority of the fed cattle deficit in the state was supplied by interstate shipments from surplus districts in Arizona (54SC) and New Mexico (55SC). It can be seen from Table 8 that surplus fed cattle in Texas that could have supplied the deficit of fed cattle in the state were shipped to other states instead.

The total surplus of fed cattle in Iowa was shipped to deficit districts outside Iowa. Surplus fed cattle were shipped from Iowa to Illinois (52SC), Michigan (66SC), and Wisconsin (38SC). The deficit of Iowa fed cattle was supplied by shipments of fed cattle from districts outside Iowa. Approximately 42.9 percent of the deficit was supplied by

TABLE 8.--Optimal Fed Cattle Shipments,Using Combination of Interstate and Intrastate Rates, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Amarillo (1SC)	Topeka (21SC)	109,906
	Little Rock (63SC)	112,617
	Jackson (68SC)	200,446
	Nashville (69SC)	246,829
	Montgomery (71SC)	70,167
	Atlanta (72SC)	160,938
	Richmond (75SC)	62,344
Lubbock (2SC)	Dallas (4SC)	64,782
	Tyler (5SC)	107,329
	Montgomery (71SC)	38,046
	Orlando (73SC)	43,818
Graham (3SC)	Dallas (4SC)	206,940
	Dover (79SC)	3,024
Ft. Stockton (6SC)	Orlando (73SC)	165,225
Laredo (8SC)	Baton Rouge (65SC)	77,253
	Orlando (73SC)	6,977
IOWA:		
Des Moines (11SC)	Dixon (52SC)	259,322
	Lansing (66SC)	9,723
Cedar Rapids (12SC)	Madison (38SC)	254,437
	Dixon (52SC)	16,953

TABLE 8--Continued

From	To	Amount
NEBRASKA:		
Valentine (13SC)	Spencer (9SC)	173,977
	Norfolk (14SC)	21,255
	Wisconsin Rapids (37SC)	557,164
	Worthington (43SC)	62,030
	Mankato (44SC)	53,143
Grand Island (15SC)	Omaha (16SC)	167,395
Holdredge (17SC)	Omaha	481,837
Beatrice (18SC)	Omaha	320,969
KANSAS:		
Salina (19SC)	Omaha (16SC)	11,774
	Topeka (21SC)	111,497
	St. Joseph (22SC)	256,196
	Trenton (80SC)	165,989
	Harrisburg (81SC)	404,781
	Providence (87SC)	7,140
Wichita (20SC)	Lexington (70SC)	156,371
	Charleston (76SC)	9,015
	Baltimore (77SC)	26,352
	Columbus (78SC)	405,835
	Harrisburg (81SC)	97,024
	Syracuse (82SC)	68,862

TABLE 8--*Continued*

From	To	Amount
Wichita (cont'd.)	Montpelier (83SC)	14,947
	Boston (84SC)	28,401
	Hartford (85SC)	11,540
	Augusta (86SC)	12,517
	Concord (88SC)	23,783
MISSOURI:		
Kirksville (23SC)	Orlando (73SC)	15,404
Hannibal (24SC)	Lansing (66SC)	6,718
Kansas City (25SC)	St. Louis (27SC)	26,632
Jefferson City (26SC)	St. Louis	32,168
	Charleston (76SC)	4,960
Joplin (28SC)	St. Louis (27SC)	2,845
West Plains (29SC)	Sikeston (30SC)	10,199
	Charleston (76SC)	26,017
OKLAHOMA:		
Oklahoma City (31SC)	Raleigh (64SC)	85,696
	Nashville (69SC)	128,312
	Columbia (74SC)	14,549
CALIFORNIA:		
Redding (32SC)	Dixon (52SC)	107,104
	Seattle (57SC)	41,016
San Jose (33SC)	Los Angeles (36SC)	55,491
	Seattle (57SC)	37,576

TABLE 8--Continued

From	To	Amount
Sacramento (34SC)	Seattle (57SC)	29,741
Fresno (35SC)	Los Angeles (36SC)	386,214
MINNESOTA:		
Bemidji (39SC)	St. Cloud (41SC)	84,205
	Minneapolis (42SC)	7,772
Fergus Falls (40SC)	Minneapolis	102,627
Rochester (45SC)	Wisconsin Rapids (37SC)	51,179
SOUTH DAKOTA:		
Huron (46SC)	Minneapolis (42SC)	39,524
	Mankato (44SC)	55,129
COLORADO:		
Greeley (48SC)	Denison (10SC)	231,332
	Norfolk (14SC)	103,925
	Omaha (16SC)	181,898
	Denver (49SC)	232,442
	Bismark (62SC)	36,290
Alamosa (50SC)	Topeka (21SC)	19,888
Pueblo (51SC)	Topeka	249,700
OTHER STATES:		
Springfield (53SC)	Lansing (66SC)	294,120
	Syracuse (82SC)	124,240
Flagstaff (54SC)	Tyler (5SC)	82,049
	San Antonio (7SC)	319,414

TABLE 8--Continued

From	To	Amount
Flagstaff (cont'd.)	Craig (47SC)	1,103
	Salt Lake City (56SC)	90,938
Albuquerque (55SC)	Tyler (5SC)	20,067
Bend (58SC)	Seattle (57SC)	11,422
Great Falls (59SC)	Bismark (62SC)	20,146
Casper (60SC)	Bismark	37,473
Indianapolis (67SC)	Augusta (86SC)	9,439
Winnemucca (89SC)	Salt Lake City (56SC)	14,550
	Boise (61SC)	18,224

Total Cost - $124,101,825

Total Shipments - 9,316,608,000 pounds (livewt.)

Total Diesel Consumption - 28,373,634 gallons

Total Distance Traveled - 120,587,944 miles

fed cattle from Nebraska (13SC), and Colorado (48SC) supplied 57.1 percent of the deficit.

Only 6.2 percent of the surplus of Kansas fed cattle was shipped to the Kansas deficit district (21SC). The remainder of surplus fed cattle was shipped from Kansas surplus districts (19SC, 20SC) to Nebraska (16SC), Missouri (22SC), New Jersey (80SC), Pennsylvania (81SC), Rhode Island (87SC), Kentucky (70SC), West Virginia (76SC), Maryland (77SC), Ohio (78SC), New York (82SC), Vermont (83SC), Massachusetts (84SC), Connecticut (85SC), Maine (86SC), and New Hampshire (88SC). The Kansas deficit district (21SC) received fed cattle from Texas (1SC) and Colorado (50SC, 51SC).

Of the surplus of California fed cattle, 67.2 percent was shipped to the one California deficit district (36SC). However, the total deficit was supplied by this amount of the surplus. The remainder of the surplus was shipped to Illinois (52SC) and Washington (57SC). California received no fed cattle from other states.

South Dakota contained only one slaughter-consumption district (46SC). The surplus fed cattle of this district were shipped to deficit districts in Minnesota (42SC, 44SC). Since there was only one slaughter-consumption district in South Dakota, there were no intrastate shipments of fed cattle.

Approximately 78 percent of the surplus of Colorado fed cattle was shipped to deficit districts outside Colorado.

Cattle were shipped to Iowa (10SC), Nebraska (14SC, 16SC), North Dakota (62SC) and Kansas (21SC). The deficit of one Colorado deficit district (49SC) was supplied by shipments of fed cattle from a Colorado surplus district (48SC). The other Colorado deficit district (47SC) received fed cattle from Arizona (54SC).

None of the surplus of Illinois fed cattle was shipped to the Illinois deficit district (52SC). Surplus fed cattle were shipped from Illinois (53SC) to Michigan (66SC) and New York (82SC). The Illinois deficit district (52SC) received shipments of fed cattle from Iowa (11SC, 12SC) and California (32SC).

Arizona contained only one slaughter-consumption district (54SC). The surplus of this district was shipped to deficit districts in Texas (5SC, 7SC), Colorado (47SC), and Utah (56SC).

The optimal solution of transporting fed cattle among 89 districts in the 48 states for the model which utilized available intrastate and interstate rates effective in 1976 involved:

(1) a total cost of $124.1 million;

(2) 9,316.6 million pounds liveweight;

(3) 28.4 million gallons of diesel;

(4) 120.6 million miles.

Table 9 contains optimal shipments of fed cattle among districts under the system of transportation costs which were

TABLE 9.--Optimal Fed Cattle Shipments, Using Estimated Shipping Costs, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Amarillo (1SC)	Dallas (4SC)	20,252
	Little Rock (63SC)	112,617
	Raleigh (64SC)	85,696
	Jackson (68SC)	200,446
	Nashville (69SC)	307,522
	Montgomery (71SC)	108,213
	Orlando (73SC)	43,818
	Columbia (74SC)	14,549
	Richmond (75SC)	62,344
	Charleston (76SC)	7,790
Lubbock (2SC)	Dallas (4SC)	44,530
	Tyler (5SC)	209,445
Graham (3SC)	Dallas (4SC)	206,940
	Dover (79SC)	3,024
Ft. Stockton (6SC)	Baton Rouge (65SC)	77,253
	Orlando (73SC)	87,972
Laredo (8SC)	Orlando	84,230
IOWA:		
Des Moines (11SC)	Dixon (52SC)	100,299
	Lansing (66SC)	168,746

TABLE 9--Continued

From	To	Amount
Cedar Rapids (12SC)	Madison (38SC)	254,437
	Dixon (52SC)	16,953
NEBRASKA:		
Valentine (13SC)	Spencer (9SC)	173,977
	Norfolk (14SC)	21,255
	Wisconsin Rapids (37SC)	557,164
	Worthington (43SC)	62,030
	Mankato (44SC)	53,143
Grand Island (15SC)	Omaha (16SC)	167,395
Holdredge (17SC)	Omaha	420,192
	St. Louis (27SC)	61,645
Beatrice (18SC)	Omaha (16SC)	320,969
KANSAS:		
Salina (19SC)	Topeka (21SC)	453,845
	St. Joseph (22SC)	256,196
	Harrisburg (81SC)	247,336
Wichita (20SC)	Lexington (70SC)	122,583
	Columbus (78SC)	378,539
	Trenton (80SC)	136,514
	Harrisburg (81SC)	214,910
	Hartford (85SC)	2,101
MISSOURI:		
Kirksville (23SC)	Orlando (73SC)	15,404

TABLE 9--Continued

From	To	Amount
Hannibal (24SC)	Montpelier (83SC)	6,718
Kansas City (25SC)	Harrisburg (81SC)	26,632
Jefferson City (26SC)	Lexington (70SC)	33,788
	Charleston (76SC)	3,340
Joplin (28SC)	Charleston	2,845
West Plains (29SC)	Sikeston (30SC)	10,199
	Charleston (76SC)	26,017
OKLAHOMA:		
Oklahoma City (31SC)	Nashville (69SC)	67,619
	Atlanta (72SC)	160,938
CALIFORNIA:		
Redding (32SC)	Dixon (52SC)	107,104
	Seattle (57SC)	41,016
San Jose (33SC)	Los Angeles (36SC)	55,491
	Seattle (57SC)	37,576
Sacramento (34SC)	Seattle	29,741
Fresno (35SC)	Los Angeles (36SC)	386,214
MINNESOTA:		
Bemidji (39SC)	St. Cloud (41SC)	84,205
	Minneapolis (42SC)	7,772
Fergus Falls (40SC)	Minneapolis	102,627
Rochester (45SC)	Wisconsin Rapids (37SC)	51,179

TABLE 9--Continued

From	To	Amount
SOUTH DAKOTA:		
Huron (46SC)	Minneapolis (42SC)	39,524
	Mankato (44SC)	55,129
Greeley (48SC)	Denison (10SC)	231,332
	Norfolk (14SC)	103,925
	Omaha (16SC)	255,317
	Dixon (52SC)	159,023
	Bismark (62SC)	36,290
Alamosa (50SC)	Topeka (21SC)	19,888
Pueblo (51SC)	Topeka	17,258
	Denver (49SC)	232,442
OTHER STATES:		
Springfield (53SC)	Lansing (66SC)	141,815
	Trenton (80SC)	29,475
	Syracuse (82SC)	193,102
	Montpelier (83SC)	8,229
	Augusta (86SC)	21,956
	Concord (88SC)	23,783
Flagstaff (54SC)	San Antonio (7SC)	319,414
	Craig (47SC)	1,103
	Salt Lake City (56SC)	90,938
	Baltimore (77SC)	26,352

TABLE 9--Continued

From	To	Amount
Flagstaff (cont'd.)	Columbus (78SC)	27,296
	Boston (84SC)	28,401
Albuquerque (55SC)	Harrisburg (81SC)	12,927
	Providence (87SC)	7,140
Bend (58SC)	Seattle (57SC)	11,422
Great Falls (59SC)	Bismark (62SC)	20,146
Casper (60SC)	Bismark	37,473
Indianapolis (67SC)	Hartford (85SC)	9,439
Winnemucca (89SC)	Salt Lake City (56SC)	14,550
	Boise (61SC)	18,224

Total Cost - $121,899,562

Total Shipments - 9,316,608,000 pounds (livewt.)

Total Diesel Consumption - 28,342,544 gallons

Total Distance Traveled - 120,455,812 miles

estimated as a function of distance. As shown in Table 9, 71.3 percent of the Texas surplus of fed cattle was shipped interstate to Arkansas (63SC), North Carolina (64SC), Mississippi (68SC), Tennessee (69SC), Alabama (71SC), Florida (73SC), South Carolina (74SC), Virginia (75SC), West Virginia (76SC), Delaware (79SC), and Louisiana (65SC). Only 28.7 percent of the surplus was shipped to destinations within Texas (4SC, 5SC), even though the Texas deficit of fed cattle was greater than 800 million pounds liveweight. Of the Texas deficit of fed cattle, 60.1 percent was supplied by shipments from surplus districts within the state (1SC, 2SC, 3SC). The remainder of the deficit was supplied by shipments of fed cattle from Arizona (54SC).

As shown in Table 9, surplus fed cattle from Iowa were shipped to the same destinations as those presented in Table 8. The only change was that Illinois (52SC) received 159 million pounds less of fed cattle, and Michigan received 159 million pounds more of fed cattle in Table 9 than in Table 8. The other destination outside Iowa was Wisconsin (38SC). Iowa deficit districts (9SC, 10SC) were supplied by the same shipments of fed cattle from Nebraska (13SC) and Colorado (48SC) as were shown in Table 8.

Approximately 25 percent of the Kansas surplus of fed cattle was shipped to the only deficit district within the state (21SC). The remainder of the surplus fed cattle were shipped from Kansas surplus districts (19SC, 20SC) to deficit districts in Missouri (22SC), Pennsylvania (81SC), Kentucky (70SC), Ohio (78SC), New Jersey (80SC), and Connecticut (85SC). Of the deficit of fed cattle in Kansas, 92.4 percent was supplied by shipments of fed cattle from surplus districts within the state. The remainder of the deficit was supplied by shipments of fed cattle from Colorado surplus districts (48SC, 50SC).

The shipping patterns for the surplus fed cattle of California presented in Table 9 are exactly the same as the shipping patterns shown in Table 8 for California. Of the surplus fed cattle, 67.2 percent were shipped to the only deficit district within the state (36SC), supplying the total deficit of that district. The remainder of the surplus was shipped to deficit districts in Illinois (52SC) and Washington (57SC).

The only slaughter-consumption district in South Dakota (46SC) maintained the same shipping patterns in the optimal solution presented in Table 9 as were presented in Table 8. Shipments of fed cattle were made to Minnesota deficit districts (42SC, 44SC).

Approximately 78 percent of the surplus of fed cattle in Colorado was shipped to deficit districts outside Colorado. Fed cattle were shipped to Iowa (10SC), Nebraska (14SC, 16SC), Illinois (52SC), North Dakota (62SC), and Kansas (21SC). The remainder of the surplus of fed cattle in Colorado were shipped to a deficit district (49SC) within the state. The only other Colorado deficit district was supplied by shipments of fed cattle from Arizona (54SC).

None of the surplus of fed cattle in Illinois was shipped to the deficit district within the state. Instead, fed cattle were shipped from the Illinois surplus district (53SC) to Michigan (66SC), New Jersey (80SC), New York (82SC), Vermont (83SC), Maine (86SC), and New Hampshire (88SC). The Illinois deficit district (52SC) was supplied by shipments of fed cattle from Iowa (11SC, 12SC), California (32SC), and Colorado (48SC).

The only slaughter-consumption district in Arizona (54SC) shipped its surplus of fed cattle to Texas (7SC), Colorado (47SC), Utah (56SC), Maryland (77SC), Ohio (78SC), and Massachusetts (84SC).

The optimal solution of transporting fed cattle among 89 districts in the 48 states for the transportation model which used shipping costs estimated as a function of distance involved:

(1) a total cost of $121.9 million;

(2) 9,316.6 million pounds liveweight;

(3) 28.3 million gallons of diesel;

(4) 120.5 million miles.

A comparison of Tables 8 and 9 reveals the differences in optimal shipping activities that were generated by the two transportation models. Texas shipped 6.1 percent more of its surplus of fed cattle to destinations within Texas in Table 9 than in Table 8. Shipments of fed cattle from Iowa changed only in that 29.4 percent of Iowa's total surplus was diverted from Illinois to Michigan in Table 9. There was no difference in shipments to Iowa deficit districts. Of the total surplus of fed cattle in Kansas, 18.8 percent more was shipped to the Kansas deficit district in Table 9. Shipments of surplus fed cattle from California and South Dakota did not change from Table 8 to Table 9. The only difference occurring in shipments of fed cattle from Colorado was that Illinois was added as a destination in Table 9. Illinois shipped to more New England states in Table 9 than in Table 8. Arizona added shipments to Maryland, Ohio, and Massachusetts in Table 9.

Non-Fed Cattle Shipments

Table 10 contains optimal shipments of non-fed cattle among districts under the combination of interstate transportation rates, which are a function of distance, and the 1976 intrastate transportation rates whenever applicable. As shown in Table 10, 42.3 percent of the surplus of non-fed cattle in Texas was shipped interstate to Kansas (21SC) and California (36SC). Of the Texas surplus, 57.7 percent was shipped to deficit districts within the state (1SC, 2SC). However, these intrastate shipments supplied only 48.4 percent

TABLE 10.--Optimal Non-Fed Cattle Shipments, Using Combination of Interstate and Intrastate Rates, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Graham (3SC)	Amarillo (1SC)	244,326
Dallas (4SC)	Amarillo	69,191
Tyler (5SC)	Topeka (21SC)	219,827
Ft. Stockton (6SC)	Amarillo (1SC)	7,102
	Los Angeles (36SC)	111,304
San Antonio (7SC)	Amarillo (1SC)	44,487
Laredo (8SC)	Amarillo	75,266
	Lubbock (2SC)	10,408
NEBRASKA:		
Valentine (13SC)	Norfolk (14SC)	217,494
Holdredge (17SC)	Grand Island (15SC)	95,102
	Omaha (16SC)	30,272
Beatrice (18SC)	Omaha	98,516
KANSAS:		
Salina (19SC)	Omaha	290,250
MISSOURI:		
Kirksville (23SC)	Des Moines (11SC)	74,991
	Omaha (16SC)	7,328
Hannibal (24SC)	Denison (10SC)	49,966
	Des Moines (11SC)	5,824
Kansas City (25SC)	Omaha (16SC)	93,281

TABLE 10--*Continued*

From	To	Amount
Jefferson City (26SC)	Omaha (16SC)	150,130
Joplin (28SC)	Omaha	69,229
	Topeka (21SC)	13,832
West Plains (29SC)	Omaha (16SC)	2,392
	St. Joseph (22SC)	105,758
Sikeston (30SC)	St. Joseph	6,220
	St. Louis (27SC)	3,024
OKLAHOMA:		
Oklahoma City (31SC)	Amarillo (1SC)	335,384
	Wichita (20SC)	279,421
CALIFORNIA:		
Redding (32SC)	San Jose (33SC)	5,845
	Sacramento (34SC)	39,257
	Fresno (35SC)	11,332
MINNESOTA:		
Bemidji (39SC)	St. Cloud (41SC)	47,432
	Minneapolis (42SC)	34,272
Fergus Falls (40SC)	Minneapolis	75,675
	Mankato (44SC)	16,526
Rochester (45SC)	Mankato	54,794
SOUTH DAKOTA:		
Huron (46SC)	Spencer (9SC)	132,797

TABLE 10--Continued

From	To	Amount
Huron (cont'd.)	Denison (10SC)	71,852
	Norfolk (14SC)	151,813
COLORADO:		
Craig (47SC)	Denver (49SC)	57,040
Alamosa (50SC)	Denver	85,180
Pueblo (51SC)	Denver	26,565
OTHER STATES:		
Springfield (53SC)	Denison (10SC)	43,938
	Cedar Rapids (12SC)	44,554
	Wisconsin Rapids (37SC)	94,490
	Madison (38SC)	29,875
Flagstaff (54SC)	Los Angeles (36SC)	91,517
Albuquerque (55SC)	Los Angeles	48,285
Salt Lake City (56SC)	Los Angeles	13,937
Bend (58SC)	San Jose (33SC)	25,621
	Los Angeles (36SC)	62,750
Great Falls (59SC)	Los Angeles	97,463
	Greeley (48SC)	110,124
	Denver (49SC)	86,334
	Seattle (57SC)	45,973
Casper (60SC)	Greeley (48SC)	213,939
Boise (61SC)	Los Angeles (36SC)	10,821
Bismark (62SC)	Spencer (9SC)	208,874

TABLE 10--Continued

From	To	Amount
Bismark (cont'd.)	Worthington (43SC)	33,409
	Mankato (44SC)	3,398
Little Rock (63SC)	Omaha (16SC)	228,532
Raleigh (64SC)	Harrisburg (81SC)	55,557
Baton Rouge (65SC)	Amarillo (1SC)	144,665
	Omaha (16SC)	18,562
Indianapolis (67SC)	Wisconsin Rapids (37SC)	97,623
	Dixon (52SC)	38,546
	Lansing (66SC)	22,852
Jackson (68SC)	Omaha (16SC)	129,550
Nashville (69SC)	Dixon (52SC)	76,103
Lexington (70SC)	Denison (10SC)	267,464
Montgomery (71SC)	Dixon (52SC)	239,748
	Columbus (78SC)	54,710
	Harrisburg (81SC)	4,318
Atlanta (72SC)	Harrisburg	58,458
Orlando (73SC)	Trenton (80SC)	7,514
	Harrisburg (81SC)	89,118
Columbia (74SC)	Harrisburg	51,151
Richmond (75SC)	Trenton (80SC)	87,764
Charleston (76SC)	Harrisburg (81SC)	27,160
	Syracuse (82SC)	22,329
Baltimore (77SC)	Trenton (80SC)	21,691

TABLE 10--Continued

From	To	Amount
Baltimore (cont'd)	Providence (87SC)	2,402
Dover (79SC)	Providence	2,076
Montpelier (83SC)	Boston (84SC)	7,319
	Augusta (86SC)	4,247
	Concord (88SC)	10,707
Hartford (85SC)	Boston (84SC)	2,572
	Providence (87SC)	274
Winnemucca (89SC)	Los Angeles (36SC)	65,739

Total Costs - $63,012,173

Total Shipments - 6,624,758,000 pounds (livewt.)

Total Diesel Consumption - 14,314,454 gallons

Total Distance Traveled - 60,836,429 miles

of the requirements of the two Texas deficit districts (1SC, 2SC). The remainder of the Texas deficit was supplied by shipments from Oklahoma (31SC) and Louisiana (65SC). Even though the deficit of non-fed cattle in Texas was greater than the surplus, more than 40 percent of the Texas surplus was shipped to destinations outside the state.

Iowa slaughter-consumption districts had no surplus of non-fed cattle. Iowa districts (9SC-12SC) received shipments of non-fed cattle from Missouri (23SC, 24SC), South Dakota (46SC), Illinois (53SC), North Dakota (62SC), and Kentucky (70SC).

The total surplus of non-fed cattle in Kansas was shipped from the Kansas surplus district (19SC) to Nebraska (16SC), even though the deficit of non-fed cattle in Kansas was greater than the surplus. The Kansas deficit districts (20SC, 21SC) were supplied by shipments of cattle from Texas (5SC), Missouri (28SC), and Oklahoma (31SC).

All of the surplus of non-fed cattle in California was shipped to deficit districts within the state (33SC-35SC). However, these shipments supplied only 9.7 percent of the deficit of non-fed cattle in California. The remainder of the California deficit was supplied by shipments of cattle from Texas (6SC), Arizona (54SC), New Mexico (55SC), Utah (56SC), Oregon (58SC), Montana (59SC), Idaho (61SC), and Nevada (89SC).

The only South Dakota slaughter-consumption district (46SC) shipped its surplus of non-fed cattle to Iowa (9SC, 10SC) and Nebraska (14SC). South Dakota received no shipments of non-fed cattle in this solution.

The total amount of the surplus of non-fed cattle in Colorado was shipped to one deficit district within the state (49SC). However, these shipments supplied only 29.1 percent of the total deficit of non-fed cattle in Colorado. The remainder of the Colorado deficit was supplied by shipments from Montana (59SC) and Wyoming (60SC).

None of the surplus of non-fed cattle in Illinois was shipped to the Illinois deficit district (52SC). Instead, interstate shipments of cattle were made to Iowa (10SC, 12SC) and Wisconsin (37SC, 38SC). The deficit of non-fed cattle in Illinois was supplied by shipments from Indiana (67SC), Tennessee (69SC), and Alabama (71SC).

The only Arizona slaughter-consumption district (54SC) shipped its surplus to California (36SC). Arizona received no shipments of non-fed cattle in this solution.

The optimal solution of transporting non-fed cattle among 89 districts in the 48 states for the model which utilized available intrastate and interstate rates effective in 1976 involved:

(1) a total cost of $63 million;

(2) 6,624.8 million pounds liveweight;

(3) 14.3 million gallons of diesel;

(4) 60.8 million miles.

Table 11 contains optimal shipments of non-fed cattle among districts under the system of transportation costs which were estimated as a function of distance. As shown in Table 11, 14.2 percent of the surplus of non-fed cattle in Texas was shipped to a deficit district in California (36SC). Of the Texas surplus, 85.8 percent was shipped to deficit districts within the state (1SC, 2SC). These intrastate shipments to Texas deficit districts supplied approximately 72 percent of the total deficit of non-fed cattle in Texas. The remainder of the state's deficit was supplied by shipments from a surplus district in Oklahoma (31SC).

The deficit of Iowa slaughter-consumption districts was supplied by shipments from districts outside Iowa since there was no surplus of non-fed cattle in the state. Iowa deficit districts (9SC-12SC) received cattle from Missouri (23SC, 24SC, 30SC), South Dakota (46SC), North Dakota (62SC), Kentucky (70SC), and Alabama (71SC).

The only surplus district in Kansas (19SC) shipped its total surplus of non-fed cattle to Nebraska (16SC). The deficit districts in Kansas (20SC, 21SC) were supplied by shipments of cattle from Missouri (28SC), Oklahoma (31SC), and Louisiana (65SC).

The total surplus of the California surplus district was shipped to one deficit district (36SC) within the state. The

TABLE 11.--Optimal Non-Fed Cattle Shipments, Using Estimated Shipping Costs, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Graham (3SC)	Amarillo (1SC)	244,326
Dallas (4SC)	Amarillo	69,191
Tyler (5SC)	Amarillo	219,827
Ft. Stockton (6SC)	Amarillo	7,102
	Los Angeles (36SC)	111,304
San Antonio (7SC)	Amarillo (1SC)	44,487
Laredo (8SC)	Amarillo	75,266
	Lubbock (2SC)	10,408
NEBRASKA:		
Valentine (13SC)	Norfolk (14SC)	217,494
Holdredge (17SC)	Grand Island (15SC)	95,102
	Omaha (16SC)	30,272
Beatrice (18SC)	Omaha	98,516
KANSAS:		
Salina (19SC)	Omaha	290,250
MISSOURI:		
Kirksville (23SC)	Denison (10SC)	31,894
	Des Moines (11SC)	50,425
Hannibal (24SC)	Denison (10SC)	55,790
Kansas City (25SC)	Omaha (16SC)	93,281
Jefferson City (26SC)	Omaha	150,130

TABLE 11--Continued

From	To	Amount
Joplin (28SC)	Topeka (21SC)	83,061
West Plains (29SC)	Omaha (16SC)	83,963
	St. Joseph (22SC)	24,187
Sikeston (30SC)	Denison (10SC)	6,220
	St. Louis (27SC)	3,024
OKLAHOMA:		
Oklahoma City (31SC)	Amarillo (1SC)	260,222
	Wichita (20SC)	279,421
	Topeka (21SC)	75,162
CALIFORNIA:		
Redding (32SC)	Los Angeles (36SC)	56,434
MINNESOTA:		
Bemidji (39SC)	St. Cloud (41SC)	47,432
	Minneapolis (42SC)	34,272
Fergus Falls (40SC)	Minneapolis (42SC)	72,277
	Mankato (44SC)	19,924
Rochester (45SC)	Mankato	54,794
SOUTH DAKOTA:		
Huron (46SC)	Spencer (9SC)	132,797
	Denison (10SC)	71,852
	Norfolk (14SC)	151,813

TABLE 11--*Continued*

From	To	Amount
COLORADO:		
Craig (47SC)	Denver (49SC)	57,040
Alamosa (50SC)	Denver	85,180
Pueblo (51SC)	Denver	26,565
OTHER STATES:		
Springfield (53SC)	Dixon (52SC)	212,857
Flagstaff (54SC)	Los Angeles (36SC)	91,517
Albuquerque (55SC)	Los Angeles	48,285
Salt Lake City (56SC)	Los Angeles	13,937
Bend (58SC)	San Jose (33SC)	31,466
	Sacramento (34SC)	39,257
	Fresno (35SC)	11,332
	Los Angeles (36SC)	6,316
Great Falls (59SC)	Los Angeles	97,463
	Greeley (48SC)	110,124
	Denver (49SC)	86,334
	Seattle (57SC)	45,973
Casper (60SC)	Greeley (48SC)	213,939
Boise (61SC)	Los Angeles (36SC)	10,821
Bismark (62SC)	Spencer (9SC)	208,874
	Minneapolis (42SC)	3,398
	Worthington (43SC)	33,409

TABLE 11--Continued

From	To	Amount
Little Rock (63SC)	Omaha (16SC)	228,532
Raleigh (64SC)	Harrisburg (81SC)	55,557
Baton Rouge (65SC)	Topeka (21SC)	75,436
	St. Joseph (22SC)	87,791
Indianapolis (67SC)	Wisconsin Rapids (37SC)	136,169
	Lansing (66SC)	22,852
Jackson (68SC)	Omaha (16SC)	129,550
Nashville (69SC)	Wisconsin Rapids (37SC)	46,228
	Madison (38SC)	29,875
Lexington (70SC)	Denison (10SC)	267,464
Montgomery (71SC)	Des Moines (11SC)	30,390
	Cedar Rapids (12SC)	44,554
	Omaha (16SC)	13,548
	Wisconsin Rapids (37SC)	9,716
	Dixon (52SC)	141,540
	Columbus (78SC)	54,710
	Harrisburg (81SC)	4,318
Atlanta (72SC)	Harrisburg	58,458
Orlando (73SC)	Trenton (80SC)	92,876
	Harrisburg (81SC)	1,354
	Providence (87SC)	2,402
Columbia (74SC)	Harrisburg (81SC)	51,151

TABLE 11--Continued

From	To	Amount
Richmond (75SC)	Harrisburg (81SC)	87,764
Charleston (76SC)	Harrisburg	27,160
	Syracuse (82SC)	22,329
Baltimore (77SC)	Trenton (80SC)	24,093
Dover (79SC)	Providence (87SC)	2,076
Montpelier (83SC)	Boston (84SC)	7,319
	Augusta (86SC)	4,247
	Concord (88SC)	10,707
Hartford (85SC)	Boston (84SC)	2,572
	Providence (87SC)	274
Winnemucca (89SC)	Los Angeles (36SC)	65,739

Total Cost - $61,497,272

Total Shipments - 6,624,758,000 pounds (livewt.)

Total Diesel Consumption - 14,266,984 gallons

Total Distance Traveled - 60,634,684 miles

remainder of the deficit of non-fed cattle in California was supplied by shipments from Texas (6SC), Arizona (54SC), New Mexico (55SC), Utah (56SC), Oregon (58SC), Montana (59SC), Idaho (61SC), and Nevada (89SC).

The shipments of non-fed cattle from the surplus district in South Dakota (46SC) shown in Table 11 were the same as those presented in Table 10. Cattle were shipped from South Dakota to Iowa (9SC, 10SC) and Nebraska (14SC). Since South Dakota contained no deficit districts, the state received no shipments of non-fed cattle from other states in this solution.

There was no difference between the shipments of surplus non-fed cattle in Colorado shown in Table 10 and the shipments of Colorado cattle shown in Table 11. The total state surplus was shipped to one Colorado deficit district (49SC) in both solutions. Montana (59SC) and Wyoming (60SC) supplied the remainder of the Colorado deficit.

All of the surplus non-fed cattle in the Illinois surplus district (53SC) were shipped to the only deficit district in Illinois (52SC). These shipments supplied 60.1 percent of the total deficit of Illinois. The remainder of the deficit was supplied by shipments of cattle from Alabama (71SC).

The Arizona surplus district (54SC) shipped its total surplus of non-fed cattle to California (36SC). Since

Arizona contained no deficit districts, the state received no shipments of non-fed cattle from other states in this solution.

The optimal solution of transporting non-fed cattle among 89 districts in the 48 states for the transportation model which utilized shipping costs estimated as a function of distance involved:

(1) a total cost of $61.5 million;

(2) 6,624.8 million pounds liveweight;

(3) 14.3 million gallons of diesel;

(4) 60.6 million miles.

A comparison of Tables 10 and 11 reveals the differences in optimal shipping activities that were generated by the two transportation models. Texas surplus districts shipped 28.1 percent more of the state's total surplus of non-fed cattle to destinations within Texas in Table 11 than in Table 10. Shipments of non-fed cattle to Iowa deficit districts changed in that Iowa received more cattle from Missouri, and Alabama replaced Illinois as a supplier in Table 11. Louisiana replaced Texas as a supplier of Kansas deficit districts in Table 11. The Los Angeles district of California received the total surplus of non-fed cattle in the state in Table 11, but the district received none of the California surplus in Table 10. There was no difference between optimal shipments of surplus cattle in South Dakota and Colorado in Tables 10 and 11. No intrastate shipments of surplus non-fed cattle in Illinois were made in Table 10, but all shipments of Illinois cattle were intrastate in Table 11. Optimal shipments of surplus cattle in Arizona were the same in Tables 10 and 11.

Beef Shipments

Table 12 contains optimal shipments of beef among districts under the combination of interstate transportation rates, which are a function of distance, and the 1976 intrastate transportation rates whenever applicable. As shown in Table 12, the total surplus of beef in Texas was shipped to destinations outside the state. Texas surplus districts (1SC-3SC, 5SC, 6SC, 8SC) shipped beef to Arkansas (63SC), Louisiana (65SC), Alabama (71SC), Georgia (72SC), Florida (74SC), South Carolina (74SC), Virginia (75SC), Mississippi (68SC), and Delaware (79SC). The Texas deficit districts (4SC, 7SC) were supplied by shipments of beef from Oklahoma (31SC) and New Mexico (55SC).

Iowa contained no districts which had deficits of beef. Therefore, all shipments of beef from Iowa surplus districts (9SC-12SC) were made to destinations outside the state. Beef shipments were made to New York (82SC), Connecticut (85SC), Maine (86SC), New Hampshire (88SC), Kentucky (70SC), Ohio (78SC), Illinois (52SC), and Vermont (83SC).

TABLE 12.--Optimal Beef Shipments, Using Combination of Interstate and Intrastate Rates, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Amarillo (1SC)	Little Rock (63SC)	153,931
	Baton Rouge (65SC)	181,790
	Montgomery (71SC)	390,961
	Atlanta (72SC)	171,881
	Orlando (73SC)	804,712
	Columbia (74SC)	393,463
	Richmond (75SC)	675,402
Lubbock (2SC)	Orlando (73SC)	101,995
Graham (3SC)	Jackson (68SC)	12,907
	Orlando (73SC)	1,048
	Dover (79SC)	96,456
Tyler (5SC)	Baton Rouge (65SC)	127,801
Ft. Stockton (6SC)	Baton Rouge	58,399
Laredo (8SC)	Baton Rouge	146,657
IOWA:		
Spencer (9SC)	Syracuse (82SC)	736,660
	Hartford (85SC)	312,378
	Augusta (86SC)	176,830
	Concord (88SC)	72,440
Denison (10SC)	Lexington (70SC)	250,445
	Syracuse (82SC)	1,386,493

TABLE 12--Continued

From	To	Amount
Des Moines (11SC)	Columbus (78SC)	741,540
	Concord (88SC)	50,800
Cedar Rapids (12SC)	Dixon (52SC)	322,374
	Montpelier (83SC)	72,853
	Hartford (85SC)	224,985
NEBRASKA:		
Valentine (13SC)	Dixon (52SC)	257,189
Norfolk (14SC)	Lansing (66SC)	490,184
	Syracuse (82SC)	621,459
	Providence (87SC)	176,704
Grand Island (15SC)	Baltimore (77SC)	577,328
Omaha (16SC)	Baltimore (77SC)	50,901
	Trenton (80SC)	1,187,192
	Harrisburg (81SC)	1,313,419
	Syracuse (82SC)	201,983
Holdredge (17SC)	St. Louis (27SC)	107,474
Beatrice (18SC)	Springfield (53SC)	7,632
KANSAS:		
Salina (19SC)	Columbus (78SC)	266,158
Wichita (20SC)	Jefferson City (26SC)	55,173
	St. Louis (27SC)	177,583
	Joplin (28SC)	19,166

TABLE 12--Continued

From	To	Amount
Wichita (cont'd.)	West Plains (29SC)	35,007
	Sikeston (30SC)	23,126
	Raleigh (64SC)	749,177
	Indianapolis (67SC)	31,945
	Nashville (69SC)	39,357
	Atlanta (72SC)	188,232
	Charleston (76SC)	255,275
Topeka (21SC)	Kansas City (25SC)	159,736
	Indianapolis (67SC)	417,082
	Columbus (78SC)	246,136
MISSOURI:		
St. Joseph (22SC)	Springfield (53SC)	211,592
	Indianapolis (67SC)	237,995
Kirksville (23SC)	Orlando (73SC)	8,498
Hannibal (24SC)	Columbus (78SC)	8,455
OKLAHOMA:		
Oklahoma City (31SC)	Dallas (4SC)	125,768
	Atlanta (72SC)	62,702
CALIFORNIA:		
Fresno (35SC)	San Jose (33SC)	359,847
WISCONSIN:		
Wisconsin Rapids (37SC)	Lansing (66SC)	739,403

TABLE 12--*Continued*

From	To	Amount
MINNESOTA:		
St. Cloud (41SC)	Minneapolis (42SC)	39,033
	Boston (84SC)	308,733
Worthington (43SC)	Syracuse (82SC)	304,619
Mankato (44SC)	Madison (38SC)	72,139
	Boston (84SC)	185,206
Rochester (45SC)	Syracuse (82SC)	53,193
SOUTH DAKOTA:		
Huron (46SC)	Boston (84SC)	637,857
	Hartford (85SC)	72,766
COLORADO:		
Greeley (48SC)	San Jose (33SC)	477,212
	Sacramento (34SC)	31,050
	Los Angeles (36SC)	292,970
	Springfield (53SC)	226,160
	Casper (60SC)	48,402
	Winnemucca (89SC)	50,646
Denver (49SC)	Los Angeles (36SC)	647,710
Pueblo (51SC)	Los Angeles	153,439
OTHER STATES:		
Flagstaff (54SC)	Los Angeles	2,980

TABLE 12--Continued

From	To	Amount
Albuquerque (55SC)	San Antonio (7SC)	162,010
	Los Angeles (36SC)	87,477
	Alamosa (50SC)	17,833
Salt Lake City (56SC)	Craig (47SC)	20,857
	Winnemucca (89SC)	12,643
Boise (61SC)	Redding (32SC)	62,383
	Seattle (57SC)	71,753
	Bend (58SC)	253,401
	Winnemucca (89SC)	53,172
Bismark (62SC)	Bemidji (39SC)	103,749
	Fergus Falls (40SC)	21,875
	Minneapolis (42SC)	8,141
	Great Falls (59SC)	12,671

Total Cost - $325,940,173

Total Shipments - 21,566,159,000 pounds (livewt.)

Tractor Fuel Consumption - 126,092,819 gallons

Refrigerator Unit Fuel Consumption - 14,335,818 gallons

Total Diesel Consumption - 140,428,637 gallons

Total Distance Traveled - 535,894,479 miles

Nebraska also contained only districts which had surplus beef. Surplus districts in Nebraska (13SC-18SC) shipped the total surplus of beef in Nebraska to destinations outside the state. Shipments of beef were made to Illinois (52SC, 53SC), Michigan (66SC), New York (82SC), Rhode Island (87SC), Maryland (77SC), New Jersey (80SC), Pennsylvania (81SC), and Missouri (27SC).

Kansas contained no districts which had deficits of beef. The total surplus of the Kansas slaughter-consumption districts (19SC-21SC) was shipped to destinations outside Kansas. Districts which received beef from Kansas were Ohio (78SC), Missouri (25SC-30SC), North Carolina (64SC), Indiana (67SC), Tennessee (69SC), Georgia (72SC), and West Virginia (76SC).

There was only one district in California (35SC) which contained a surplus of beef. The total surplus of this district was shipped to one of the deficit districts in California (33SC). These shipments supplied only approximately 17 percent of the total deficit of beef in California. The remainder of the deficit was supplied by shipments of beef from Colorado (48SC, 49SC, 51SC), Arizona (54SC), New Mexico (55SC), and Idaho (61SC).

The total surplus of beef in Colorado slaughter-consumption districts was shipped to destinations outside Colorado. Colorado surplus districts (48SC, 49SC, 51SC) shipped beef to California (33SC, 34SC, 36SC), Illinois (53SC), Wyoming (60SC), and Nevada (89SC). Colorado deficit districts (47SC, 50SC) were supplied by shipments of beef from New Mexico (55SC) and Utah (56SC).

The deficit of the two Illinois slaughter-consumption districts (52SC, 53SC) was supplied by shipments of beef from districts outside Illinois since there was no surplus of beef in the state. Beef was received from surplus districts in Iowa (12SC), Nebraska (13SC, 18SC), Missouri (22SC), and Colorado (48SC).

The optimal solution of transporting beef among 89 districts in the 48 states for the transportation model which utilized available intrastate and interstate rates effective in 1976 involved:

(1) a total cost of $325.9 million;

(2) 21,566.2 million pounds liveweight;

(3) tractor fuel consumption of 126.1 million gallons of diesel;

(4) refrigerator unit fuel consumption of 14.3 million gallons of diesel;

(5) total diesel consumption of 140.4 million gallons;

(6) 535.9 million miles.

Table 13 contains optimal shipments of beef among districts under the system of transportation costs which were estimated as a function of distance. As shown in Table 13, 91.3 percent of the total surplus of beef in Texas was shipped

TABLE 13.--Optimal Beef Shipments, Using Estimated Shipping Costs, by Originating Districts, 1976, 48 States

From	To	Amount
TEXAS:		
Amarillo (1SC)	Little Rock (63SC)	153,931
	Baton Rouge (65SC)	343,800
	Jackson (68SC)	12,907
	Montgomery (71SC)	390,961
	Atlanta (72SC)	287,384
	Orlando (73SC)	907,755
	Richmond (75SC)	675,402
Lubbock (2SC)	Dallas (4SC)	101,995
Graham (3SC)	Dallas	23,773
	Dover (79SC)	86,638
Tyler (5SC)	Baton Rouge (65SC)	127,801
Ft. Stockton (6SC)	San Antonio (7SC)	58,399
Laredo (8SC)	San Antonio	103,611
	Baton Rouge (65SC)	43,046
IOWA:		
Spencer (9SC)	Syracuse (82SC)	1,298,308
Denison (10SC)	Lexington (70SC)	250,445
	Syracuse (82SC)	1,386,493
Des Moines (11SC)	Trenton (80SC)	792,340
Cedar Rapids (12SC)	Dixon (52SC)	342,125
	Lansing (66SC)	28,530

TABLE 13--Continued

From	To	Amount
Cedar Rapids (cont'd.)	Montpelier (83SC)	72,853
	Providence (87SC)	176,704
NEBRASKA:		
Valentine (13SC)	Dixon (52SC)	237,438
	Syracuse (82SC)	19,751
Norfolk (14SC)	Boston (84SC)	678,218
	Hartford (85SC)	610,129
Grand Island (15SC)	Columbus (78SC)	182,476
	Trenton (80SC)	394,852
Omaha (16SC)	Baltimore (77SC)	628,229
	Columbus (78SC)	549,246
	Dover (79SC)	9,818
	Harrisburg (81SC)	1,313,419
	Boston (84SC)	129,543
	Concord (88SC)	123,240
Holdredge (17SC)	St. Louis (27SC)	107,474
Beatrice (18SC)	Springfield (53SC)	7,632
KANSAS:		
Salina (19SC)	Indianapolis (67SC)	266,158
Wichita (20SC)	Jefferson City (26SC)	55,173
	St. Louis (27SC)	57,336
	Joplin (28SC)	19,166

TABLE 13--Continued

From	To	Amount
Wichita (cont'd.)	West Plains (29SC)	35,007
	Sikeston (30SC)	23,126
	Raleigh (64SC)	749,177
	Nashville (69SC)	39,357
	Columbia (74SC)	340,424
	Charleston (76SC)	255,275
Topeka (21SC)	Kansas City (25SC)	159,736
	St. Louis (27SC)	120,247
	Indianapolis (67SC)	20,859
	Columbus (78SC)	522,112
MISSOURI:		
St. Joseph (22SC)	Springfield (53SC)	437,752
	Indianapolis (67SC)	11,835
Kirksville (23SC)	Orlando (73SC)	8,498
Hannibal (24SC)	Columbus (78SC)	8,455
OKLAHOMA:		
Oklahoma City (31SC)	Atlanta (72SC)	135,431
	Columbia (74SC)	53,039
CALIFORNIA:		
Fresno (35SC)	San Jose (33SC)	359,847
WISCONSIN:		
Wisconsin Rapids (37SC)	Lansing (66SC)	739,403

TABLE 13--Continued

From	To	Amount
MINNESOTA:		
St. Cloud (41SC)	Minneapolis (42SC)	39,033
	Syracuse (82SC)	37,891
	Boston (84SC)	270,842
Worthington (43SC)	Syracuse (82SC)	304,619
Mankato (44SC)	Syracuse	257,345
Rochester (45SC)	Boston (84SC)	53,193
SOUTH DAKOTA:		
Huron (46SC)	Madison (38SC)	72,139
	Lansing (66SC)	461,654
	Augusta (86SC)	176,830
COLORADO:		
Greeley (48SC)	San Jose (33SC)	424,040
	Sacramento (34SC)	31,050
	Los Angeles (36SC)	151,817
	Casper (60SC)	48,402
	Indianapolis (67SC)	388,170
	Winnemucca (89SC)	82,961
Denver (49SC)	Los Angeles (36SC)	626,853
	Craig (47SC)	20,857
Pueblo (51SC)	Los Angeles (36SC)	135,606
	Alamosa (50SC)	17,833

TABLE 13--Continued

From	To	Amount
OTHER STATES:		
Flagstaff (54SC)	Los Angeles (36SC)	2,980
Albuquerque (55SC)	Los Angeles	267,320
Salt Lake City (56SC)	Winnemucca (89SC)	33,500
Boise (61SC)	Redding (32SC)	62,383
	San Jose (33SC)	53,172
	Seattle (57SC)	71,753
	Bend (58SC)	253,401
Bismark (62SC)	Bemidji (39SC)	103,749
	Fergus Falls (40SC)	21,875
	Minneapolis (42SC)	8,141
	Great Falls (59SC)	12,671

Total Cost - $321,974,329

Total Shipments - 21,566,159,000 pounds (livewt.)

Tractor Fuel Consumption - 125,416,037 gallons

Refrigerator Unit Fuel Consumption - 14,077,757 gallons

Total Diesel Consumption - 139,493,795 gallons

Total Distance Traveled - 533,018,158 miles

to destinations outside Texas. Beef was shipped to Arkansas (63SC), Louisiana (65SC), Mississippi (68SC), Alabama (71SC), Georgia (72SC), Florida (73SC), Virginia (75SC), and Delaware (79SC). Only 8.7 percent of the total surplus of beef in Texas was shipped to districts within the state (4SC, 7SC). However, these shipments supplied the total beef deficit of Texas districts.

The total surplus of beef in Iowa was shipped to districts outside Iowa since the state contained no deficit districts. Iowa surplus districts (9SC-12SC) shipped beef to New York (82SC), Kentucky (70SC), New Jersey (80SC), Illinois (52SC), Michigan (66SC), Vermont (83SC), and Rhode Island (87SC).

The surplus districts of Nebraska (13SC-18SC) shipped surplus beef to deficit districts outside Nebraska. Shipments were made to Illinois (52SC, 53SC), New York (82SC), Massachusetts (84SC), Connecticut (85SC), Ohio (78SC), New Jersey (80SC), Maryland (77SC), Delaware (79SC), Pennsylvania (81SC), New Hampshire (88SC), and Missouri (27SC). Iowa received no shipments of beef since there were no deficit districts in the state.

Kansas surplus districts (19SC-21SC) shipped beef to deficit districts in Indiana (67SC), Missouri (25SC-30SC), North Carolina (64SC), Tennessee (69SC), South Carolina (74SC), West Virginia (76SC), and Ohio (78SC). Since there were no deficit districts in Kansas, no beef was shipped into the state from other districts.

Shipments of beef from the California surplus district (35SC) were the same in Tables 12 and 13. The total surplus of beef in California was shipped to a California deficit district (33SC). The remainder of the beef deficit was supplied by shipments of beef from Colorado (48SC, 49SC, 51SC), Arizona (54SC), New Mexico (55SC), and Idaho (61SC).

Approximately 98 percent of the surplus of beef in Colorado was shipped to deficit districts outside Colorado. Beef was shipped from Colorado surplus districts (48SC, 49SC, 51SC) to California (33SC, 34SC, 36SC), Wyoming (60SC), Indiana (67SC), and Nevada (89SC). Only 2 percent of the surplus of beef was shipped to deficit districts within Colorado (47SC, 50SC). However, these shipments to Colorado districts supplied the total deficit of the state.

Since there was no surplus of beef in Illinois, districts in the state (52SC, 53SC) were supplied by shipments of beef from districts outside Illinois. Beef was received from surplus districts in Iowa (12SC), Nebraska (13SC, 18SC), and Missouri (22SC).

The optimal solution of transporting beef among 89 districts in the 48 states for the transportation model which utilized shipping costs estimated as a function of distance involved:

(1) a total cost of $322 million;

(2) 21,566.2 million pounds liveweight;

(3) tractor fuel consumption of 125.4 million gallons of diesel;

(4) refrigerator unit fuel consumption of 14.1 million gallons of diesel;

(5) total diesel consumption of 139.5 million gallons;

(6) 533 million miles.

A comparison of Tables 12 and 13 reveals the differences in optimal shipping activities that were generated by the two transportation models. When shipping costs were estimated as a function of distance, Texas surplus districts shipped 8.7 percent more of the state's total surplus of beef to destinations within Texas than when rates effective in 1976 were used. Shipments of beef from Iowa changed in that more beef was shipped to New England states as shown in Table 13. Nebraska districts diverted shipments of beef from Michigan and Rhode Island to Massachusetts, Connecticut, Ohio, Delaware, and New Hampshire in Table 13. Surplus districts in Kansas changed the pattern of beef shipments by shipping less beef to Missouri and Ohio, ending shipments to Georgia, and shipping to South Carolina instead. Shipments of surplus beef in California were the same in Tables 12 and 13. Of the surplus beef in Colorado, 2 percent was used to supply the total Colorado deficit in Table 13, while the deficit was supplied by districts outside the state in Table 12. Colorado was not a supplier of Illinois in Table 13 even though it was the second-largest supplier of Illinois in Table 12.

Comparison of Results

A comparison of the final results of each of the optimal solutions previously discussed is given in Table 14. In each instance, using shipping costs estimated as a function of distance instead of the available 1976 interstate and intrastate rates resulted in reductions in total cost, diesel consumption, and distance traveled. The greatest difference in total costs which resulted from utilizing the two different types of rate structure was approximately $4 million in the beef transportation model. However, the greatest percentage change in total costs was 2.40 percent in the non-fed cattle model. The largest difference in total diesel consumption, 934.8 thousand gallons, was also in the beef model. A change of 1.37 percent in total diesel consumption occurred in the feeder cattle model and was the largest percentage change in diesel consumption. The greatest difference in distance traveled was approximately 2.9 million miles and was in the beef model also. The largest percentage change in total distance traveled, 1.37 percent, was in the feeder cattle model. Since tractor fuel consumption and refrigeration unit fuel consumption were estimated only in the beef model, no comparison could be made of these factors in other models.

TABLE 14.--Comparison of Optimal Solutions, by Commodities Shipped, 1976, 48 States

		Total Cost	Total Shipments (lbs.)
FEEDER CATTLE	Interstate & Intrastate Rates	$149,180,703	10,664,724,000
	Estimated Shipping Costs	$146,666,282	10,664,724,000
	Difference	$ 2,514,421	-0-
	% Change	1.69	-0-
FED CATTLE	Interstate & Intrastate Rates	$124,101,285	9,316,608,000
	Estimated Shipping Costs	$121,899,562	9,316,608,000
	Difference	$ 2,201,723	-0-
	% Change	1.77	-0-
NON-FED CATTLE	Interstate & Intrastate Rates	$ 63,012,173	6,624,758,000
	Estimated Shipping Costs	$ 61,497,272	6,624,758,000
	Difference	$ 1,514,901	-0-
	% Change	2.40	-0-
BEEF	Interstate & Intrastate Rates	$325,940,173	21,566,159,000
	Estimated Shipping Costs	$321,974,329	21,566,159,000
	Difference	$ 3,965,844	-0-
	% Change	1.22	-0-

* Equal to Total Diesel Consumption.

+ Refrigeration unit used only for beef shipments.

TABLE 14--Continued

Total Diesel Consumption (gal.)	Total Distance Traveled (mi.)	Tractor Fuel Consumption (gal.)	Refrigeration Unit Fuel Consumption (gal.)
34,497,446	146,614,145	*	+
34,025,497	144,608,364	*	+
471,949	2,005,781		
1.37	1.37		
28,373,634	120,587,944	*	+
28,342,544	120,455,812	*	+
31,090	132,132		
0.11	0.11		
14,314,454	60,836,429	*	+
14,266,984	60,634,684	*	+
47,470	201,745		
0.33	0.33		
140,428,637	535,894,479	126,092,819	14,335,818
139,493,795	533,018,158	125,416,037	14,077,757
934,842	2,876,321	676,782	258,061
0.67	0.54	0.54	1.80

CHAPTER VI

SUMMARY AND CONCLUSIONS

Transportation of agricultural products represents a major use of petroleum fuels in the United States. This transportation makes up a major portion of the marketing cost of agricultural commodities since most agricultural production takes place in rural areas and most consumption occurs in widely separated urban centers. This fact becomes even more apparent when it is considered that cattle travel through various production stages before they reach the final consumer as beef. Since there may be considerable distance between these stages of production, there is a large volume of transportation involved in the production, feeding, packing, and final sale of cattle or beef. The various shipping rates effective for this transportation in 1976 did not necessarily reflect a concern for efficient petroleum energy use. Consequently, least-cost shipping routes of 1976 could have resulted in a considerable misallocation of fuel and energy in transporting cattle and beef.

The major objective of this research was to compare the 1976 rate structure for the shipment of cattle and beef by truck with a rate structure consisting solely of rates which are a function of distance in order to determine possible petroleum fuel savings for the nation. A linear programming transportation model was used to analyze each of the several movements of cattle and beef in order to achieve this objective.

The continental United States were divided into 148 production-feeding districts and 89 slaughter-consumption districts, each consisting of one or more crop reporting districts. Estimates of production, feeding, slaughter and consumption were acquired from published data or developed, as discussed earlier, for each of the appropriate districts. Each of these estimates was in liveweight equivalents. Due to difficulty in acquiring data, it was necessary to split the district estimates into a "feeding" sector, a "non-feeding" sector and a "total" sector. The "feeding" sector included the movements of cattle produced for feeding purposes from production to feeding to slaughter of fed cattle marketed. The "non-feeding" sector covered the movements of grass-fed cattle from grazing to slaughter of non-fed cattle. As explained earlier, it was assumed that cattle produced for non-feeding purposes were moved to grazing areas within their original production district. Consequently, no movement from production to grazing was analyzed. The "total" sector included the movements of beef from slaughter (fed plus non-fed slaughter) to consumption. Despite the use of these sectors, it was still assumed that total production, total cattle marketed for slaughter, total slaughter and total civilian consumption were all equal. This assumption eliminated consideration of carry-over, imports, and exports.

District shortages or surpluses of feeder cattle were estimated by comparing production for feeding purposes with fed cattle marketed for slaughter in each district. Fed cattle marketed in each district was compared with fed cattle slaughtered to estimate district surpluses or shortages of fed cattle. The surplus or deficit of non-fed cattle in each district was determined by comparing non-fed cattle marketed for slaughter and non-fed cattle slaughtered. Beef surplus or shortage in each district was estimated by comparing total slaughter with total civilian consumption in each district.

Transportation models utilizing the district shortages and surpluses described above were applied to each movement of cattle and beef being analyzed. Each movement was analyzed under both of the rate structures described at the beginning of this chapter. The available transportation rates in effect in 1976 were obtained from state regulatory agencies and major trucking firms.

This analysis has been performed under the assumptions of pure competition. These assumptions include:

(1) a large number of buyers and sellers who are unable to affect the price of the commodity through individual actions;

(2) absolute freedom of entry into and exit from the market;

(3) excellent mobility of inputs;

(4) no outside or artificial restraints on the operation of the market;

(5) all buyers and sellers have perfect knowledge of market conditions;

(6) a homogeneous product so that consumers are indifferent to the source of the commodity.

In reality, these characteristics of pure competition are not completely fulfilled. Cattle and beef are not homogeneous within themselves. Grading practices are evidence of the quality variation within each commodity and consumer awareness of these variations. Capital requirements in the cattle-beef industry often restrict entry into the enterprise and mobility of resources. Buyers and sellers in the market rarely have complete knowledge of all market situations.

However, pure competition conditions serve to simplify a complex analysis such as this one. These conditions also provide a normative sense to the entire analysis, since the linear programming model is normative. Consequently, the results provide an indication of what would happen if conditions of pure competition prevailed and the least-cost shipping routes were followed. The results were biased by the assumptions of pure competition, but the extent of the bias was not quantifiable.

Summary

The comparative analysis of each movement of cattle and beef under the two rate structures described above demonstrates that total shipping costs and total diesel consumption for optimal shipments are less in the system which contains shipping rates as a function of distance in each instance. The movement of feeder cattle from production to feeding cost over $2.5 million less, used 471,949 gallons of diesel less, and saved over 2 million miles of driving when rates as a function of distance were applied than when the rates effective in 1976 were used. These values represent a 1.7 percent reduction in cost and 1.4 percent reduction in diesel consumption and total distance traveled.

Optimal shipments of fed cattle to slaughter under the system of rates as a function of distance showed savings of more than $2.2 million in costs, 31,090 gallons of diesel, and 132,132 miles in total distance traveled. Costs decreased by 1.8 percent while diesel consumption and distance traveled were reduced by 0.11 percent.

The movement of non-fed cattle from grazing to slaughter cost over $1.5 million less, used 47,470 gallons of diesel less, and saved 201,745 miles in total distance traveled when the estimated rates were used than when the actual rates were applied. Consequently, savings of 2.4 percent in costs and 0.33 percent in diesel consumption and mileage traveled were realized.

Beef shipments were also less expensive and used less diesel when rates based upon the distance traveled were used. The optimal shipments cost approximately $4 million less, used 934,842 gallons of diesel less, and saved 2,876,321 miles in distance traveled. These savings represent reductions of 1.2 percent in cost, 0.7 percent in total fuel consumption, and 0.54 percent in distance traveled.

Considering all of the movements of cattle and beef, total savings in 1976 could have been approximately $10.2 million in costs, 1,485,351 gallons of diesel, and 5,215,979 miles in total distance traveled. It is apparent that, under the assumptions of this research, the largest potential for conservation of diesel fuel exists in the areas of shipping feeder cattle and beef.

Conclusions

Based on the analysis of least-cost shipments of cattle and beef under the two shipping rate structures discussed above, it can be seen that least-cost shipping routes for the rates effective in 1976 differ somewhat from the shipping routes that would minimize diesel consumption. While the potential savings of petroleum fuel presented earlier in this chapter may not seem as great as might be expected, it must be remembered that some of the major assumptions made in this study were intended to maintain very conservative estimates of fuel conservation.

One such assumption was that cattle produced for nonfeeding purposes were grazed in their original production district. This eliminated any inter-district movement of these cattle and, consequently, any potential fuel savings derived from using the alternative rate structure.

Another assumption that insured conservative estimates of fuel savings was that shipping rates which were a function of distance would apply where intrastate rates were not available and for all interstate rates. Since the shipping rates in use in 1976 were not necessarily a function of distance, the use of rates that were a function of distance in conjunction with actual rates may well have kept fuel conservation estimates lower than they might have been otherwise.

Also, due to data incompatability, there was no available method of converting the district slaughter estimates for the 89 slaughter-consumption districts into district estimates for the 148 production-feeding districts. Slaughter estimates were not a function of production, cattle on feed, or marketings. Therefore, it was necessary to aggregate the 148 production-feeding districts into the 89 slaughter-consumption districts before movements of fed and non-fed cattle marketed for slaughter could be analyzed. The assumption made was that fed and non-fed cattle marketed for slaughter were transported among the 89 slaughter-consumption districts, not from production-feeding districts to slaughter-consumption districts. The results were that potential shipments were eliminated from the analysis, and fuel conservation estimates could have been higher.

One other assumption that may have prevented higher fuel conservation estimates was that no cross-hauling was allowed. This simplified the analysis, but in reality there may be some cross-hauling of the commodities. If such is the case, the fuel savings estimates would probably have been higher.

Further research in the area of quantifying district estimates of cattle produced for non-feeding purposes, non-fed cattle marketed for slaughter, and non-fed cattle slaughtered would be very useful for future analyses of this type. At present, very little data exist which would allow more exact estimates of these variables.

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