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AN ECONOMIC ANALYSIS OF ALTERNATIVE GRAIN TRANSPORTATION SYSTEMS: A CASE STUDY

IOWA STATE UNIVERSITY

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16. Abstract

This report presents the results of research conducted to determine which grain transportation system would yield the highest net income in a 6½-county area around Fort Dodge, Iowa. Transportation alternatives considered include the traditional single-car rail system, multiple rail car shipments of 3, 50, 80 and 115 cars, truck, truck-barge and rail-barge. It was assumed that sub-terminals would be required to load the shipments of 50 cars or more. Also, alternative rail line options were considered: these included maintaining the 1971 rail system, maintaining and upgrading 100 percent, 46 percent and 27 percent of the 1971 rail lines to permit trains with jumbo hoppers to travel at least 35 miles per hour. Total investment requirements were estimated for selected grain distribution systems. The evaluated alternatives were ranked in terms of total joint net income, investment requirements and capacity to move grain with minimum congestion within the entire grain distribution system. Finally, institutional problems related to moving to higher income alternatives are identified. This study is an in-depth analysis of one intensive grain production area. A second analysis at the aggregate level encompassing the United States was conducted cooperatively with this study. The results of the aggregate study are reported in Interrelationships of Grain Transportation, Production, and Demand: A Cost Analysis and Projection of Grain Shipments within the United States for 1980 by Jerry A. Fedeler, Earl O. Heady, and Won W. Koo (Phase II).

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Chapter I
Introduction

The physical distribution system for America's corn and soybeans has been criticized as being unresponsive to the needs of the grain industry, and slow to adjust to technological and economic change. In January of 1973 a grain elevator manager located in central Iowa stated:

> For the past five years our cooperative has suffered because of a transportation crisis. At present time we have been out of the corn market since December 15,1972. We have the ownership and contracts of 1½ million bushels of corn and 465,000 bushels of soybeans. To date we have our loan capital of $2 million borrowed to finance this grain. In the past four weeks we have moved by rail 32 cars, one half being open-top coal cars. At this rate it will take two years to move our inventory, not taking into consideration the grain inventory that is still on the farm. Iowa farmers are desperate to move their cash grain!

Corn and soybeans are becoming increasingly important products in domestic and international trade. From 1962-63 to 1972-73, U.S. corn and soybean production increased from 4.3 billion bushels to 6.8 billion bushels. During this same time period, corn and soybean exports almost tripled, increasing from 538 million bushels to 1.5 billion bushels.

This dramatic increase in grain production and grain exports has contributed to storage and transportation problems. During the 1969-70 marketing year, when large quantities of grain moved to export markets, shippers had great difficulty obtaining transportation equipment to fulfill their contract commitments to both domestic and foreign buyers. A severe transportation crisis occurred again, in the fall of 1972 and winter of 1973 as reflected in the statement at the beginning of this section. And, according to an Iowa State University News release in the spring of 1973, "transportation problems are expected to remain serious this summer (1973) as Iowa elevators try to move roughly 50 million more bushels than we have transportation capacity for".

Other changes have also affected the grain distribution system. Innovations in grain harvesting have permitted farmers to move huge quantities of corn and soybeans into storage or to market in short periods of time. In 1964, only ten percent of the corn crop in Iowa was shipped to elevators during the harvesting season. In 1972 , 32 percent of the corn crop moved directly to elevators during harvest season. This, coupled with temporary shortages of transportation services, has often forced elevator managers to store thousands of bushels of shelled corn on streets and roads.

Innovations have also occurred in the transportation system. Railroads have issued multiple-car rates which are significantly lower than single-car rates. The single-car export rate for shipping corn, for example, from a station near Fort Dodge, Iowa to Chicago is 19 cents per bushel; the 50-car rate to the same location is only 12 cents per bushel.

In addition to multiple-car shipments, railroads are also encouraging the use of larger size rail cars for the transport of grain. The jumbo covered hopper car, capable of hauling up to 3,300-3,500 bushels of grain, is rapidly replacing the 2,000 bushel-capacity box car. The number of 40-foot box cars in the United States has declined from 563,470 in 1960 to 212,000 cars in 1973. During the same period of time, covered hopper cars increased from 64,255 to 186,219 cars.

These innovations, however, have not solved the grain transportation problems. In fact, such innovations tend to complicate the problems of some elevator operators. Many of the rail lines in grain producing regions were designed for early 1900 technology. Some of the rail lines require upgrading and/or repair to make them capable of carrying the heavy hopper cars and multiple-car trains. The decline in the number of 40-foot box cars and encouragement of multiple-car shipments by rail carriers, place the elevators on light branch rail lines at a considerable disadvantage.

Railroad officials contend that the large number of rail lines in grain producing regions preclude an efficient rail system. Although there seems to be a general agreement among railroad officials that too many branch lines are in existence, there is considerable uncertainty regarding how many and which lines should be closed.

The various stages of grain production, conditioning, storage, and transportation, which constitute the physical distribution system for grain are highly interdependent. The growth or adjustment of one stage should complement the other stages within the marketing channel. In attempting to decide which lines should be maintained, location of storage facilities must be considered. And, likewise, location of storage facilities must take into consideration the long-run adjustment plans of the railroads as expansion or relocation of processing facilities are scheduled.

Predicting the future actions of other market participants, however, is very difficult. Integration either vertical or horizontal, or explicit collusion between stages of the distribution channel are ways to circumvent problems of uncertainty. The pricing system may provide information concerning equilibrium prices, production possibilities, and preferences, but often fails to provide adequate signals or information concerning the expansion plans of other members of the distribution channel. In this sense, the competitive pricing system fails to serve as an efficient guide for decision making.

A lack of information concerning the behavior or future plans of other marketing participants may delay or prolong the needed industry adjustments until additional information can be obtained. With insufficient information the marketing industry may attempt to adjust to a state of disequilibrium through a process of trial-and-error. This process often causes the adjustment path to be circuitous and indirect and, thus, less than optimal.

The extent to which industry resources are misallocated by delaying the adjustment process and/or following a circuitous adjustment path depends to a large degree on the size of the required capital investments or disinvestments. An industry in a state of disequilibrium following a structural change may adjust in various ways. The industry may, for example, be able to simply change prices or output with very little change in plant equipment. In the search for the equilibrium configuration of prices and output there may be some misallocation of resources. In the event, however, that large changes in capital equipment are required, such as rail line abandonment or the construction of a large subterminal, the misallocation of resources resulting from a circuitous adjustment path is significant.

The public sector has also raised questions regarding the propriety of rail line abandonment: What impact would the closure of various rail lines have on the road system or community? Closing a rail line may impose certain costs on society that should be weighed against the benefits of the abandonment.

One would expect a significant increase in the use of a road system if many rail lines were abandoned. An elevator, located on an abandoned rail line, for example, handling 1.6 million bushels of grain yearly would require an 800-bushel truck to make 2,000 trips to move the grain previously moved by rail.

The social costs resulting from rail abandonment could come from several sources. 1) The additional use of the road system by trucks adds to road congestion. 2) Additional public investment to upgrade and maintain the road network may be required to handle the increased use of trucks. And 3) increased truck usage, relative to rail, may result in additional energy requirements to transport grain.

In summary, recent innovations in grain harvesting and rail transportation, and changes in the supply of and demand for feed grains are some of the factors disrupting the grain distribution system. The production of corn and soybeans is increasing; larger volumes of grain are moving to more distant markets; new harvesting techniques are forcing huge quantities of corn and soybeans into elevator storage or market in short periods of time; railroad carriers are introducing multiple-car shipping rates, encouraging the use of jumbo covered hopper cars, reducing the number of 40-foot box cars, and proposing the abandonment of a significant proportion of track mileage; and, neither the pricing system nor regulatory policies are adequately designed to coordinate or facilitate the industry adjustments needed to insure an efficient physical distribution system and provide for the general transportation needs of the grain industry.

Innovations and changes in grain processing, transportation, and production are the source of many uncertainties and questions. Which rail lines should be abandoned? Where should grain handling facilities be located and how large should they be? And, what are the advantages of various grain distribution systems? Those who attempt to determine which rail lines should be abandoned often find that the location of subterminals must first be determined. Those who attempt to determine where subterminals should be located discover that it depends on the future of the rail network . . . and so it goes. The overall purpose of this study was to account for some of these interdependencies of grain marketing and determine the economics of alternative rail-based grain distribution systems within a specific region.

> The idea of searching for a better system is at least as ancient as Plato's Republic, but it is only recently that tools have become available for a systematic, analytical approach to such search procedures. This new approach refuses to accept the institutional status quo of a particular time and place as the only legitimate object of interest and yet recognizes constraints that disqualify naive utopias.

The general objective of this research was to determine a grain distribution system which would yield the highest net revenue within a given region. Specifically, the objectives of this research were to:

I. Fully describe the selected region's grain marketing system in terms of:
   A. The location and quantities of grains produced, by type, the timing of harvest, local consumption and off-farm marketings.
   B. The number, location, capacity and throughput of storage and conditioning facilities within the region, including country and other elevators. A description of the transportation interface at these storage points, such as track capacity and ability to load box cars and/or covered hoppers.
   C. Destination of region's grain, including export terminals and transit points.
   D. The transportation network serving the region, including water carriage, if any, in terms of shipper access points, terminal location, lines and routes, and amount and type of grains carried in each vehicle type as well as mode.

II. Develop the costs of storage, conditioning, and transportation of grain within the region:
   Based upon actual observation and analysis as well as engineering estimates, develop the costs of grain storage and conditioning within the region. Develop the costs of on-farm storage and conditioning. Specifically identify the nature of the costs developed in each sector as related to the following factors:
   1. Level of investment and economies of scale.
   2. Operations and maintenance costs per unit of grain produced or handled.
   Develop measures of truck, barge and rail rates within the region for the transportation of grain, and relate these rates to the amount and quality

of transportation service demanded. Where necessary, develop estimates of transportation costs by mode, including those of proprietary motor carriage.

III. Forecast the production and off-farm consumption of grains produced within the region:

Develop forecasts, at least through 1980, of the type and amount of grains that will be produced within the region. The forecasting procedure should take into account the amounts consumed by local livestock, regional and national commodity demand indications and the importance of the region in comparison with estimates of future production in other areas.

IV. Develop and analyze a series of rail-based transportation/storage alternatives. Using the studies and analyses performed above, develop a series of physical distribution alternatives for the region that utilizes some form of rail service, such as single or multiple car or trainload shipments. The alternatives developed are not required to be constrained by current practice or regulations, but must be technically, economically and financially feasible. Discussion of each alternative should include the amount, nature and type of transportation service needed, including vehicle/car type; the location, nature and capacities of storage and conditioning facilities, and any other factors or relevance to the analysis. The costs, charges and investments associated with each alternative should be completely specified.

V. Select the alternative that will produce the least cost of physical distribution for the region's grains, subject, but not limited to the following considerations and constraints:

A. The magnitude of the investments required.

B. The financial viability and general profitability of the production, storage and transportation components in the distribution system selected.

C. The flexibility of the system with respect to change in destination and customer service requirements, quantities of grain produced, and sensitivity to change in grain price or transportation costs.

Show how the distribution system selected fulfills these requirements, both in relation to the current system and the other alternatives that have been developed.

VI. Discuss the conditions and circumstances required to successfully implement the alternative selected. Develop appropriate recommendations for change in public policy and indicate areas where further research is required. With respect to the alternative selected in the previous task, fully describe the conditions, circumstances and limitations associated with the successful use of this alternative.

Chapter II
Method of Analysis

The nature and scope of the problem statement suggests a method of analysis based on a transhipment-locational model. Transhipment plant-location models are used to determine the optimal structure of an industry when transportation costs are important from origin to plant and from plant to destination. A Stollsteimer type model was selected for use in this study. The specifications of this model are presented in Appendix A.

The model is a two stage multi-period transhipment plant-location model. The method of solution is based on a combinatorial algorithm which systematically compares alternative grain distribution systems and selects the optimal configuration based upon the criteria of maximum joint net revenue for producers. This section presents the assumptions of the model and a restatement of the problem.

The transhipment plant-location model and the method of solution are based on the following assumptions and problem statement: The supply of grain at each origin is known for time t. Each grain producer located in the selected region has the option of shipping his known monthly supply of grain to either a country elevator or to a subterminal elevator. The elevator can store and ship grain to a subterminal or to a final destination. A subterminal can store and ship to a final destination. "Final destinations" refer to either export markets or domestic processing markets.

A country elevator receives grain from producers which is stored and then shipped by truck to a subterminal, or by truck, rail, or rail-barge to a final destination. A subterminal may receive grain from producers and country elevators. Grain received by a subterminal will be stored and then shipped by multiple-car rail shipments to final destinations. Country elevators located on light rail lines cannot take advantage of jumbo hopper cars or multiple-car rail shipments. Country elevators located on heavy lines cannot ship multiple hopper car shipments in excess of ten cars.

Grain received at an elevator during time t may be stored from t to t', t = 1, 2, ..., 12; t' = t + 1, ..., 12. The length of time that grain is stored depends, in part, on monthly prices at terminal markets, seasonal transportation rates and elevator capacity. Monthly demand prices are known and vary by commodity and over time for each destination. Transportation rates are also known and vary over time and by commodity.

The costs of handling grain at elevators are separated into two components: 1) total annual cost of constructing or expanding an elevator; and 2) marginal operating and maintenance costs of receiving, storing, and loading out grain at elevators. Marginal operating and maintenance costs are independent of the volume handled, but vary by commodity. The marginal operating cost of storing one bushel, however, depends upon the length of time the commodity is stored. Marginal operating costs of receiving include the operating cost of drying the grain and, thus, vary by time period. And, marginal operating costs of load out depend upon the mode of transportation used to ship grain to terminal markets.

Total annual costs of establishing or expanding an elevator involve the costs of constructing or expanding receiving, drying, storage, and load out facilities. Elevators require a certain minimum capacity of facilities. Country elevators require a driveway, receiving pits, scales, driers, and other facilities all of which are necessary to perform the functions of a country elevator. Subterminals require greater receiving and drying capacity than country elevators because subterminals receive grain from both farmers and country elevators. Subterminals also require greater load-out capacity than country elevators because subterminals load multiple-car trains.

Thus, because of the indivisibilities of construction and minimum capacity requirements of elevators, total elevator expansion or construction costs of receiving, drying, and load-out are independent of volume but vary by elevator type. To expand a country elevator to a subterminal requires upgrading receiving, drying, and load-out facilities to meet the minimum capacity requirements of a subterminal. Total annual construction or expansion costs of storage consist of 1) a fixed cost that reflects the minimum annual cost of constructing storage facilities and 2) a marginal expansion cost that reflects the additional elevator costs of expansion to store one bushel of grain.

Some grain distribution facilities, including elevators and rail lines, exist at the beginning of the planning horizon. Existing country elevators may continue in use and may be expanded into subterminals. Some new subterminals may be constructed. And, some rail lines may be abandoned and other lines upgraded.

Facilities that exist at the beginning of the planning horizon affect the optimal path of industry adjustment due to the nature of their "sunk" costs. Existing storage facilities of elevators will always be used to capacity before any elevator will expand or additional storage facilities are constructed. This takes into account 1) the sunk costs of prior investments as compared to the actual costs of expansion; and 2) marketing rigidities from producers preferring to patronize local elevators. Total construction and/or expansion costs, therefore, vary by location and depend upon the size of the existing facility.

Economies of size in rail transportation result from both the fixed set up costs of rail line installation and maintenance, and the economies of transporting large volumes of grain. Total rail transportation costs, therefore, include: 1) a minimum cost of establishing and/or maintaining a branch rail line; and 2) the marginal costs of shipping from elevator to destination which depends upon the type of elevator and minimum rate available. The minimum transport rates or cost available to a country elevator, for example, may be a single-car rail shipment. Subterminals, on the other hand, have access to multiple rail car shipments.

The objective function of the model is to maximize joint net revenue. Net revenue is the income received at final destination minus all handling costs other than previously sunk costs and all transportation costs. The detailed procedures for the solution of the model are spelled out in Appendix A.

Chapter III
The Data

Data required to evaluate the economics of alternative grain distribution systems using a generalized transhipment plant-location model include: 1) the supply of grain forthcoming from each origin in each month; 2) the demand price at each terminal market in each month; 3) elevator grain handling costs for receiving, storing, and load-out activities; and 4) transportation costs which include the upgrading and maintenance costs of alternative rail systems as well as the costs of shipping grain from point to point.

The time horizon over which alternative rail-based grain distribution systems were evaluated extends to 1980. Thus, a description of the distribution facilities existing at the beginning of the planning horizon, 1970-71, is necessary to estimate the additional investment requirements needed to implement various marketing systems.

The specific region selected for this study was a 6½ county area in central Iowa around Fort Dodge. This region, referred to in this report as the Fort Dodge area, includes the counties of Pocahontas, Hamilton, Humboldt, Webster, Greene, Calhoun, and the west half of Boone County. This area was selected for a regional analysis of the economics of grain distribution because: 1) it produces a large quantity of surplus grain. In 1970, 71 million bushels of corn and soybeans were shipped to either processing or export markets; and, by 1980 it has been estimated that almost 118 million bushels will be sold for commercial purposes. 2) There are a large number of light rail lines in the area which are not capable of handling fully loaded hopper cars. Of the 702 miles of rail line in the Fort Dodge area, only 43.9 percent of the lines were capable of handling fully loaded hopper cars. And, 3) farmers and elevator operators in the Fort Dodge area requested and helped initiate this study.

<u>Commercial Grain Supply</u>

In this section, annual grain supplies are first estimated by origin for 1970 and 1980; and secondly, the monthly supplies of grain by origin are estimated.

Annual grain supply

Grain produced within the region is either consumed locally or transhipped through elevators and shipped to final markets. For this study the commercial grain supply was defined as grain moving out of the local region where it was produced. Grain consumed by livestock within the Fort Dodge area was defined as non-commercial grain. Farms or origins were defined as three-mile square areas, generally equivalent to one-fourth of a township.

Quantities of commercial grain from each township in 1960 and 1970 and projections to 1980 were estimated. Estimates of on-farm corn, oats, and soybean usage by township were used to estimate commercial grain supply for 1960 and 1970. The difference between reported grain production and estimated usage on farms was assumed to be sold through commercial channels.

Annual commercial corn sales were defined as corn production in a township minus the amount of corn fed to livestock. Corn fed to livestock was estimated by multiplying the number of head of each type of livestock fed each year by the corn feeding rate for that type of livestock.

Since only a small amount of soybeans are normally used on farms, annual soybean sales were defined as soybean production minus one bushel of soybean seed per acre used for soybean production. Oat sales were estimated by multiplying production times the percent of oats sold off farms as reported in the 1964 U.S. Census of Agriculture. The residual oats were assumed to have been fed to livestock on farms. Corn, soybean, and oats sales were added to obtain annual estimates of commercial grain sales for 1960 and 1970.

Recent USDA projections of national grain, livestock and poultry production in 1980 served as a base for developing 1980 estimates of the Fort Dodge region production. The procedure used in making these estimates was to examine past trends in the Iowa share of U.S. production, to project the Iowa share of national production to 1980, and to translate these shares into production estimates for the state, counties, and townships. The resulting estimates using the percentage share procedure were defined as derived demand estimates.

State projections of 1980 production were allocated among counties by multiplying projected state production by each county's projected share of the state total. County projections were allocated among townships within the Fort Dodge region in a similar fashion. Projected county and township shares were derived by computing a linear time trend of production for each county and township to 1980 and then dividing this forecast by the sum of all county or townships' projections.

All grain projections allocated among townships or counties were constrained by the estimated cropland available. If more cropland was needed to satisfy the grain production forecasts for a region than the cropland available in 1967, production estimates for both corn and soybeans were decreased until the number of acres required to satisfy 1980 projections were equal to the actual cropland available in 1967. In order to satisfy the state's share of national production, the production estimates that were subtracted from regions with acreage constraints were redistributed among the remaining regions with free or idle acres.

Table 1 presents the bushels of grain produced, number of livestock, and estimated bushels of grain marketed through commercial channels in 1960 and 1970 and projections to 1980 in the 6½ counties in the Fort Dodge area.

Corn production in the area was projected to reach about 105 million bushels by 1980 according to the derived demand method. This would be a 36 percent increase from the 1970 level, or an average yearly growth rate of 3.6 percent. Corn sales according to derived demand projections would increase to about 75 million bushels in 1980. This would be an increase of 60 percent over the 1970 level, or an average growth rate of six percent per year. Soybean production was projected to increase 76 percent between 1970 and 1980.

Monthly grain supply from origins

Grain is harvested and dried in the fall and stored for consumption throughout the year. Over the past several years there has been a significant change in harvesting techniques that has brought a larger volume of grain off the farm during the fall harvesting months. The amount of grain moving off the farm in the fall as a proportion of total grain movement increased from 31 percent in 1964 to 46 percent in 1969 for the state of Iowa. In a twelve-county district in which part of the Fort Dodge area is located, the amount of grain moving off the farm in the fall as a proportion of total grain movement increased from 29 percent in 1964 to 59 percent in 1969. The increase in the amount of corn moving from the farm to elevators in the fall reflects to a large extent the increasing use of corn

Table 1.

Bushels of Grain Production, Number of Livestock, and Estimated Bushels of Grain Sold through Commercial Channels in 1960 and 1970 and Derived Demand Projections to 1980 in Thousands of Units in the Fort Dodge Area, Iowa.

	Actual		Derived Demand
	1960	1970	1980
Corn Production	70,211	77,351	104,836
Soybean Production	12,215	25,186	44,120
Oat Production	15,458	3,986	812
Milk Cows	31	7	1
Beef Cows	43	42	59
Hogs Marketed	928	1,106	1,113
Grain Fed Cattle	164	285	369
Sheep and Lambs	90	62	37
Hens and Pullets	1,609	1,651	2,275
Turkeys	1,797	1,383	987
Corn Sales	44,599	46,583	74,807
Soybean Sales	11,779	24,450	43,146
Oat Sales	8,071	2,089	416
Grain Sales	64,449	73,122	118,369

field shelling. Field shelled corn requires the use of aeration and drying equipment, which is often more accessible at elevators during harvest than on farms.

Because of increased foreign and domestic demand for corn and soybeans, it was assumed that government storage and reseal programs would not exist in 1980 or that the net flow of grain into and out of these programs would be zero. Reseal grain is owned by farmers, but stored under price support programs for an extended period of time.

A survey was taken in the Fort Dodge area to estimate the monthly flow of grain from farms to elevators. The monthly flow of grain from farms to elevators, as reported by elevator managers for the 1970 crop year, was used to estimate the monthly flow of grain in 1980 for the Fort Dodge region. To obtain the 1980 monthly supply of commercial corn and soybeans, the 1970 estimated monthly flow of of grain was adjusted to reflect changes in 1) Commodity Credit Corporation corn and soybean storage, 2) harvesting techniques, 3) grain production and the relatively lower costs of drying and storing grain in elevators compared with on-farm storage. An analysis of on-farm and elevator drying and storage costs is presented in Appendix B. This analysis indicates that normally, there would be a cost advantage in building additional storage capacities at country elevators or subterminals rather than on farms because of greater utilization of equipment.

The estimated monthly flow of commercial corn and soybean sales from farms to elevators for 1970-71 in the Fort Dodge area and projections to 1980 are presented in Table 2. The estimated 1980 monthly percentage flows from farm to elevator are presented in Table 3.

Destinations of 1970-71 grain shipments

Historically, grain shipped from elevators to markets was usually shipped to an inspection point for intransit inspection. For example, grain shipped from Fort Dodge to the Gulf typically was first billed to Des Moines for inspection and then billed from Des Moines to the Gulf.

Elevator managers usually do not maintain records of the routing of grain beyond the first billing. Between May 1971 and April 1972, however, the Interstate Commerce Commission permitted railroad companies to add a charge for each car diverted for intransit inspection. To avoid this additional charge elevator

Table 2.

Estimated Monthly Commercial Corn and Soybean Shipments from Farms to Elevators in the Fort Dodge Area in 1970-71 and Derived Demand Projections to 1980 in Thousands of Bushels.

Month	1970-71		1980	
	Corn	Soybeans	Corn	Soybeans
October	6,661	7,604	17,954	21,573
November	12,112	1,638	33,665	2,157
December	1,677	367	4,488	863
January	1,304	856	2,244	1,294
February	1,490	1,223	1,496	1,294
March	1,024	1,174	748	1,726
April	1,398	1,858	1,496	2,589
May	2,097	2,053	1,496	2,589
June	4,705	2,885	3,740	3,452
July	5,217	1,907	2,992	2,589
August	5,451	953	2,992	863
September	3,447	1,932	1,496	2,157
Total	46,583	24,450	74,807	43,146

Table 3.

Estimated Percent Distribution of Receipts of Corn and Soybeans at Elevators from Farms in the Fort Dodge Area, by Months, 1980.

Month	Percent of Total Receipts: Corn	Soybeans
October	24	50
November	45	5
December	6	2
January	3	3
February	2	3
March	1	4
April	2	6
May	2	6
June	5	8
July	4	6
August	4	2
September	2	5
Total	100	100

managers within the Fort Dodge area discontinued intransit inspection billing during this time period and shipped almost all grain directly to markets. Thus, it was possible, for this one-year period, to obtain an estimate of the quantity of grain flowing from the Fort Dodge region to various markets.

In the summer of 1972 a census was taken of all elevators within the 6½-county area to obtain data on the quantities of grain shipped by rail from each elevator to specific destinations. Information from this census, as well as information obtained from the elevator questionnaire, were used to construct Tables 4, 5, and 6.

Estimated monthly receipts, storage and shipments by rail and truck from all elevators in the Fort Dodge area from October 1970 to September 1971 are reported in Table 4. Monthly storage was defined as cumulative monthly receipts minus cumulative shipments plus grain carried over from the previous year. From the questionnaire it was estimated that 19,565,000 bushels of grain were carried over from September 1970 to October 1970.

Table 5 contains the estimated rail shipments of corn and soybeans to eleven markets from the Fort Dodge area in thousands of bushels from October 1970 to September 1971. Table 6 contains the estimated monthly rail shipments by market for corn and soybeans from the Fort Dodge region in thousands of bushels from October 1970 to September 1971.

Market demand prices

Corn and soybean prices at terminal markets vary in response to changes in the demand and supply of grain. Grain is harvested in the fall and consumed throughout the year. Prices, therefore, vary over time to reflect the costs of storage, risk, and shrinkage or damage.

Prices also vary among markets over time. The Chicago export price may be higher than the Gulf export price during one month and lower during another month. Changes in overseas or domestic demands; the freezing of the St. Lawrence Seaway or upper Mississippi; or any other condition, such as dockstrikes or queues from transportation or processing bottlenecks, tend to have a greater influence on some markets than on other markets.

Throughout this study final markets represent either 1) export markets at Chicago, Milwaukee, and the Gulf or 2) domestic markets located in Central Iowa,

Table 4.

Estimated Monthly Commercial Corn and Soybean Receipts Storage, and Shipments by Rail and Truck at Country Elevators, in the Fort Dodge Area in Thousands of Bushels, 1970-1971.

Month	Receipts	Storage	Shipments	
			Rail	Truck
October	14,265	28,891	2,725	2,214
November	13,750	37,899	2,977	1,765
December	2,044	36,388	2,286	1,268
January	2,160	33,128	4,093	1,328
February	2,713	31,543	3,252	1,045
March	2,198	28,226	4,707	809
April	3,256	26,469	4,285	727
May	4,150	23,213	6,493	913
June	7,590	20,412	9,120	1,271
July	7,124	17,926	8,308	1,303
August	6,404	17,574	5,671	1,084
September	5,379	19,565	2,529	859
Total	71,033		56,446	14,587

Table 5.

Estimated Rail Shipments of Corn and Soybeans to Eleven Markets from the Fort Dodge Area in Thousands of Bushels, October 1970 to September 1971.

Market	Thousands of Bushels			Percent of Total
	Corn	Soybeans	Total	
Central Iowa	3,459	4,153	7,612	13.5
Eastern Iowa	12,762	2,541	15,303	27.1
Chicago Export	2,684	6,610	9,294	16.5
Chicago Domestic	4,137	211	4,348	7.7
Central Illinois	3,038	1,174	4,212	7.5
Milwaukee Export	2,098	703	2,801	5.0
Milwaukee Domestic	1,840	51	1,891	3.4
Kansas	2,696	233	2,929	5.2
Nebraska	1,604	331	1,935	3.3
Missouri	1,331	313	1,644	2.9
Gulf	1,224	3,253	4,477	7.9
Total	36,873	19,573	56,446	100.0

Table 6.

Estimated Monthly Rail Shipments of Corn and Soybeans to Eleven Markets from the Fort Dodge Area in Thousands of Bushels, October 1970 to September 1971 .

	Months											
Market	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Central Iowa	954	756	433	890	514	519	624	1,118	457	565	494	289
Eastern Iowa	656	513	885	1,354	1,270	1,750	2,104	1,790	1,624	1,160	1,344	852
Chicago Export	407	101	3	0	0	3	35	1,300	3,857	2,784	497	309
Chicago Domestic	41	0	79	186	33	91	161	870	949	932	732	274
Central Illinois	3	91	137	228	232	222	186	568	643	706	1,028	168
Milwaukee Export	219	301	21	9	0	4	31	73	479	725	662	274
Milwaukee Domestic	17	31	14	7	0	61	59	336	473	514	308	71
Kansas	30	280	190	439	314	496	458	62	78	226	315	38
Nebraska	90	419	386	550	108	60	97	47	58	13	22	84
Missouri	46	344	40	150	34	98	86	132	284	217	121	92
Gulf Export	263	142	100	278	745	1,403	442	197	217	466	148	77
Total	2,725	2,977	2,286	4,093	3,252	4,707	4,285	6,493	9,120	8,308	5,671	2,529
Percent of Total	4.8	5.3	4.0	7.3	5.8	8.3	7.6	11.5	16.2	14.7	10.0	4.5

Eastern Iowa, Chicago, Central Illinois, Milwaukee, Kansas, Nebraska, and Missouri. The following cities were chosen to represent general marketing areas: New Orleans and Houston for the Gulf, Des Moines for Central Iowa, Cedar Rapids for Eastern Iowa, Pekin for Central Illinois, Kansas City for Kansas, Omaha for Nebraska, and St. Louis for Missouri.

Prices during the 1969-70 and 1970-71 crop years were used to allocate the flow of 1980 grain among markets and months. These prices were obtained from bid cards prepared weekly by the Farmers Grain Dealers Association of Iowa (Cooperative). It was assumed that sellers of grain contracting to deliver grain at a given destination during a given month would select the highest bid prevailing during month t. The highest thirty-day bid for corn and soybeans in month t and destination j was selected as an approximation for the price at that market. The actual delivered prices used in this study are presented in Tables 7, 8, 9, and 10.

Prices net of transportation at Jefferson, Iowa are presented in Table 11. It is clear from this table that net prices were higher at export markets than at domestic markets in 1969-70. The reverse was true for 1970-71. Thus, 1969-70 prices will be used to reflect a possible price pattern if exports are assumed to be strong in 1980 and the 1970-71 price will be used to reflect a domestically oriented price pattern for 1980. It is important to point out that the actual price level differences between these two years is not important for this study. The basic objective of this study is to determine which physical distribution system will yield the highest net revenue given a set of grain prices.

Grain handling facilities

This section contains a description of the grain handling facilities in existence in 1971 in the Fort Dodge area and the various costs of handling grain. The number, location, and capacity of elevators are presented as well as track capacity and load out facilities. Handling costs include 1) variable operating and maintenance costs of receiving, storing, and loading out grain; and 2) minimum fixed set-up and expansion costs for a subterminal elevator capable of loading 50-, 80- and 115-car trains.

Existing facilities

The number, size, and location of elevators in the Fort Dodge area in 1970-71 were determined from the results of elevator questionnaires. In several of the

Table 7.

Monthly Delivered Corn Prices in Cents per Bushel
at Selected Markets, 1969-70 Crop Year.

	Months											
Market	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Central Iowa	$1.08	$1.10	$1.08	$1.16	$1.16	$1.13	$1.18	$1.20	$1.24	$1.26	$1.35	$1.34
Eastern Iowa	--	--	--	--	--	1.16	1.18	1.24	1.28	1.27	1.42	1.40
Chicago Export	1.16	1.17	--	--	--	--	1.28	1.30	1.31	1.34	1.32	--
Chicago Domestic	1.20	1.23	1.22	1.27	1.27	1.26	1.28	1.33	1.36	1.34	1.43	1.51
Central Illinois	--	--	--	--	--	1.08	1.09	1.12	1.18	1.18	1.22	--
Milwaukee Export	1.16	1.17	--	--	--	--	1.28	1.30	1.31	1.34	1.32	--
Milwaukee Domestic	--	--	--	--	--	1.08	1.09	1.12	1.18	1.18	1.22	--
Kansas	1.20	1.23	1.22	1.24	1.26	1.25	1.27	1.30	1.32	1.36	1.42	1.48
Nebraska	1.12	1.12	1.13	1.19	1.18	1.16	1.18	1.22	1.20	1.24	1.34	1.41
Missouri	1.20	1.23	1.22	1.24	1.26	1.25	1.27	1.30	1.32	1.36	1.42	1.48
Gulf Export	1.27	1.27	1.29	1.33	1.31	1.30	1.36	1.38	1.42	1.38	1.48	1.59

Source: Farmers Grain Dealers Association of Iowa (Cooperative) Overnight Bid Cards.

Table 8.

Monthly Delivered Soybean Prices in Cents per Bushel at Selected Markets, 1969-70 Crop Year.

Month	Central Iowa	Eastern Iowa	Chicago Export	Chicago Domestic	Gulf Export
	Markets				
October	$2.39	$2.41	$2.43	$2.45	$2.56
November	2.41	2.42	2.45	2.45	2.58
December	2.45	2.49	--	2.54	2.62
January	2.51	2.54	--	2.59	2.68
February	2.55	2.58	--	2.63	2.68
March	2.54	2.58	--	2.63	2.71
April	2.60	2.64	2.66	2.69	2.75
May	2.68	2.72	2.72	2.77	2.83
June	2.81	2.84	2.88	2.89	2.98
July	2.85	2.88	2.92	2.93	3.04
August	2.78	2.80	2.80	2.85	2.93
September	2.81	2.84	2.85	2.88	2.95

Source: Farmers Grain Dealers Association of Iowa (Cooperative) Overnight Bid Cards.

Table 9.

Monthly Delivered Corn Prices in Cents per Bushel
at Selected Markets, 1970-71 Crop Year.

Market	Months											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Central Iowa	$1.46	$1.42	$1.42	$1.35	$1.40	$1.47	$1.41	$1.14	$1.10	$1.32	$1.26	$1.36
Eastern Iowa	1.52	1.52	1.44	1.43	1.45	1.52	1.44	1.24	1.00	1.32	1.37	1.41
Chicago Export	--	--	--	1.48	1.49	1.50	1.46	1.27	1.19	1.37	1.39	--
Chicago Domestic	1.62	1.57	1.55	1.50	1.55	1.60	1.56	1.25	1.26	1.43	1.47	1.56
Central Illinois	1.41	1.40	1.38	1.34	1.34	1.38	1.32	1.10	1.02	1.24	1.24	1.34
Milwaukee Export	--	--	--	1.48	1.49	1.50	1.46	1.27	1.19	1.37	1.39	--
Milwaukee Domestic	1.41	1.40	1.38	1.34	1.34	1.38	1.32	1.10	1.02	1.24	1.24	1.34
Kansas	1.52	1.48	1.47	1.48	1.53	1.54	1.52	1.28	1.17	1.44	1.42	1.50
Nebraska	1.45	1.44	1.42	1.43	1.46	1.49	1.46	1.22	1.20	1.38	1.34	1.42
Missouri	1.52	1.48	1.47	1.48	1.53	1.54	1.52	1.28	1.17	1.44	1.42	1.50
Gulf Export	1.64	1.60	1.57	1.56	1.58	1.66	1.58	1.38	1.28	1.51	1.50	1.60

Source: Farmers Grain Dealers Association of Iowa (Cooperative) Overnight Bid Cards.

Table 10.

Monthly Delivered Soybean Prices in Cents per Bushel at Selected Markets, 1970-71 Crop Year.

	Markets				
Month	Central Iowa	Eastern Iowa	Chicago Export	Chicago Domestic	Gulf Export
October	$2.97	$3.01	$3.01	$3.06	$3.06
November	3.00	3.02	3.04	3.05	3.10
December	2.89	2.91	--	2.95	3.04
January	3.02	3.05	--	3.10	3.19
February	3.04	3.06	--	3.10	3.19
March	2.99	3.02	--	3.08	3.17
April	2.91	2.95	2.95	3.00	3.07
May	3.05	3.08	3.11	3.14	3.20
June	3.17	3.21	3.24	3.26	3.34
July	3.44	3.47	3.48	3.51	3.60
August	3.27	3.29	3.30	3.32	3.39
September	3.14	3.18	3.24	3.23	3.32

Source: Farmers Grain Dealers Association of Iowa (Cooperative) Overnight Bid Cards.

Table 11.

Comparative Monthly Prices of Corn Less Transportation Cost from Jefferson to Chicago Domestic and Chicago Export Markets in Cents per Bushel 1969-70 and 1970-71 Crop Years (1).

	1969-70		1970-71	
Month	Chicago Domestic	Chicago Export	Chicago Domestic	Chicago Export
October	$1.01	$1.02	$1.24	$1.23
November	1.04	1.03	1.28	1.25
April	1.09	1.14	1.31	1.34
May	1.14	1.16	1.36	1.35
June	1.17	1.17	1.41	1.36
July	1.15	1.20	1.37	1.32
August	1.24	1.18	1.06	1.13
September	1.32	(2)	1.07	1.05

(1) St. Lawrence Seaway closed December-March.
(2) No bids available.

communities in the study area two elevators were located near each other. In ten of these locations the capacities of the two elevators in the community were combined and the two elevators considered as one operation. This adjustment made a total of 87 elevators in the Fort Dodge area in 1970-71.

Storage capacity is often used as a measure of elevator size. This measure, however, fails to reflect the capacity of the elevator in terms of the through-flow of grain over time. In addition to storage capacity; receiving, drying, and load-out capacities are also important dimensions of elevator size.

Capacity at elevators in 1971 to receive, dry, store, and load-out both commercial and non-commercial grain was reported by elevator managers in elevator questionnaires. Commercial grain refers to grain that is shipped out of the Fort Dodge area to markets; non-commercial grain is consumed locally by livestock. From the elevator questionnaire it was estimated that nine percent of the grain received at elevators returns to farms for the feeding of livestock. The capacity to receive, dry, store, and load-out commercial grain in 1971 was based upon the capacities reported by the elevator managers. These estimated capacities are reported in Table 12.

Receiving capacity was defined as the number of bushels of corn and soybeans that elevators can receive in one hour. The estimated average capacity of receiving commercial corn and soybeans simultaneously was 4,200 bushels per hour for the 87 elevators in the elevator survey.

Drying capacity was defined as the total rated capacity of dryers at five percent moisture removal per hour. The estimated average drying capacity for each elevator in 1971 was 1,200 bushels of commercial corn per hour.

Storage capacity was reported as the number of bushels of flat and upright storage space available on January 1, 1971. The average storage capacity for commercial grain for elevators was 484,000 bushels. The average maximum storage capacity used during the 1971 harvest season was 90 percent. For 1980 it was assumed that 15 percent of 1971 storage capacity would be used for grain carried over from one year to the next.

Load-out capacity for the 87 elevators in the Fort Dodge area was estimated by asking each manager the number of bushels of grain they could load-out in an eight-hour day by box car, hopper car, and truck.

In 1971 only 58 percent of the elevators in the study area were located next

Table 12.

Estimated Total and Average Elevator Capacity to Receive, Dry, Store, and Load-Out Commercial Grain in the Fort Dodge Area by Storage Capacity in Thousands of Bushels, 1971.

Activity	Storage Capacity 0-400	401-800	Over 800	Total
Receiving: bushels per hour				
Total	85.2	227.2	83.8	396.2
Average	2.8	4.5	6.0	4.2
Drying: bushels per hour				
Total	21.8	51.0	26.4	99.2
Average	0.9	1.2	1.9	1.2
Storage				
Total	6,502.7	24,462.0	16,399.3	47,035.9
Average	188.7	426.9	1,171.3	484.4
Percent Used	96.0	89.0	88.0	90.0
Load-out: Bushels per hour				
Total	113.8	285.7	105.6	506.0
Average	1.7	2.2	2.8	2.2

to rail lines that could handle fully loaded 100-ton hopper cars. Of the 87 elevators surveyed, only eight elevators had sufficient rail siding to load twenty or more hopper cars. Forty-two percent of the elevators had rail siding capacity for holding less than ten hopper cars.

Handling costs

Grain handling activities were divided into receiving, storing, and load-out. Receiving was defined to include the receipt of grain and the drying and conditioning of the grain. Load-out was defined to include blending, sampling, and all operations involved in loading the grain into various modes of transportation.

For this study two types of elevators were specified. Country elevators, the first type, received grain from producers and shipped to final destinations either directly or indirectly through other elevators. All corn received by country elevators during the harvest months was dried. All grain was shipped by either truck or rail using single-car rates or three- to ten-car rates. Country elevators, by definition, were unable to load-out more than ten cars either because of the condition of the track that serves the elevator or the receiving and load-out capacity of the elevator. Elevators located on light rail lines were assumed to be able to load only 40-foot box cars.

Subterminal elevators, the second type of elevator, received grain from producers and country elevators. Commercial grain received at subterminals was stored and shipped to final destinations. All corn received during the harvest season from producers was dried at the subterminal. Grain received from country elevators was assumed to have been dried at the country elevators. Subterminal elevators had the option of shipping by truck or by rail using multiple-car shipping rates. Subterminals could load-out these trains because of their location or heavy rail lines and load-out capacity.

Marginal operating and maintenance costs at elevators

Marginal operating and maintenance costs were estimated by analyzing grain elevator records and by personal interviews with elevator managers. Marginal receiving and load-out operating costs were assumed to be independent of volume handled.

Marginal operating costs of receiving grain varied by month to reflect various moisture conditions of corn. During October, November, and December it was assumed that corn required ten points of moisture removed. From January through March, corn was assumed to require four points of moisture removed. During the remainder of the year, corn received at elevators from farms required no drying. Marginal receiving costs, assuming ten, four, and zero points moisture removed from corn, were estimated as 4.58, 2.90, and 1.78 cents per bushel. The marginal operating and maintenance cost for receiving soybeans was estimated to be 1.78 cents per bushel for all months. These variable operating and maintenance costs of receiving grain are consistent with the receiving costs of 1.77 cents per bushel estimated by the Economic Research Service of USDA.

Marginal operating and maintenance costs of storing grain varied by commodity and by the length of time the grain was stored. The marginal cost of storing a bushel of corn one month was estimated to be 1.04 cents which includes 0.70 cents for interest costs based on interest rates of seven percent per year. The cost of storing a bushel of corn for more than one month was estimated by multiplying the number of months in storage by the monthly storage cost. The marginal cost of storing a bushel of soybeans was estimated as 1.97 cents per month which includes 1.63 cents for interest costs based on an interest rate of seven percent per year. Soybeans are more costly to store than corn because of the difference in price between the two commodities. A greater interest or opportunity cost of money is incurred when financing the storage of soybeans as compared to corn. The variable storage cost, net of interest expense, of .34 cents per bushel per month is comparable to the .33 cents estimated in the USDA study.

Marginal load-out cost of operating and maintenance varied by elevator type. The physical design and layout of a subterminal is engineered to load-out multiple-car trains in a short period of time. The marginal load-out cost for a subterminal elevator was estimated to be .55 cents per bushel. This estimate was based on the financial records of an existing subterminal. The load-out cost for a country elevator was estimated to be 1.74 cents. The variable operating and maintenance cost of loading out grain at country elevators was taken from Cost of Storing and Handling Grain in Commercial Elevators 1970-71, ERS Bulletin 501 USDA.

Receiving and load-out costs to transfer grain from trucks or rail cars into barges were taken from ERS Bulletin 513, USDA. The estimated cost for receiving grain from trucks and loading into barges was 3.54 cents per bushel. The estimated cost of receiving grain by rail and loading into barges was 3.85 cents per bushel.

In this study, grain handling and railroad investments existing in 1971 were considered to be "sunk" costs. That is, no investment costs were charged for these facilities. Only variable costs were charged for the operation of existing facilities. Studies which ignore facilities that exist at the beginning of the planning horizon presuppose either costless mobility of resources or facilities that are completely divisable requiring no intial setup costs. In the event that plant expansion is discontinuous or resources cannot be moved without cost, then such studies may bias the solution in favor of new facilities.

In the Fort Dodge region there were 87 elevator locations and 702 miles of rail line in existence in 1971. Some elevators and rail lines possibly were neither of the best location nor size to minimize variable assembly, handling, or distribution costs. Any savings, however, that may result from expansion and/or relocation must be weighed against the costs of adjustment.

Minimum capacities required to receive, dry, and load-out grain at subterminals were specified by elevator managers and elevator engineering consultants. Additional investments to receive, dry, and load-out grain at subterminals were estimated by subtracting the existing 1971 capacity from the minimum capacity requirements of a subterminal.

It was estimated that loading 50-car train units at a subterminal would require a receiving capacity of 15,000 bushels per hour; drying capacity of 3,000 bushels per hour; and load-out capacity of 20,000 bushels per hour. For the 80-car train, receiving, drying, and load-out capacities were assumed to be 22,500, 4,500, and 30,000 bushels per hour respectively. The assumed requirements for the 115-car train were 30,000, 6,000, and 40,000 bushels per hour.

Capacities of facilities existing at the beginning of the planning horizon, 1971, were estimated from the elevator questionnaires and are presented in Table 13 along with additional requirements at the potential subterminal sites.

Expansion costs were estimated by synthetically constructing various size elevators. The additional investment costs for receiving and load-out for the three sizes of trains considered are presented in Table 14. The detailed procedure for estimating these costs are contained in Appendix C.

Table 13.

Estimated 1971 Receiving and Load-Out Capacity in Thousands of Bushels per Hour at Selected Potential Subterminal Sites and Additional Capacity Requirements to Load 50-Car, 80-Car and 115-Car Trains.

	1971 Capacity		Additional Capacity Requirements					
			50-Car		80-Car		115-Car	
Location	Receiving	Load out	Receiving	Load out	Receiving	Load Out	Receiving	Load out
Angus	5.0	1.0	10.0	19.0	17.5	29.0	25.0	39.0
Beaver	8.0	6.2	7.0	13.8	14.5	23.8	22.0	33.8
Blairsburg	8.5	3.1	6.5	16.9	14.0	26.9	21.5	36.9
Bode	12.0	3.0	3.0	17.0	10.5	27.0	18.0	37.0
Duncombe	1.5	2.5	13.5	17.5	21.0	27.5	28.5	37.5
Ellsworth	6.0	2.5	9.0	17.5	16.5	27.5	24.0	37.5
Farnhamville	6.0	3.0	9.0	17.0	16.5	27.0	24.0	37.0
Fonda	5.9	3.1	9.1	16.9	16.6	26.9	24.1	36.9
Gilmore City	5.0	1.7	10.0	18.3	17.5	28.3	25.0	38.3
Gowrie	0.0	0.0	15.0	20.0	22.5	30.0	30.0	40.0
Hardy	8.0	2.5	7.0	17.5	14.5	27.5	22.0	37.5
Havelock	7.5	2.5	7.5	17.5	15.0	27.5	22.5	37.5
Humboldt	9.0	1.2	6.0	18.8	13.5	28.8	21.0	38.8
Jefferson	15.0	11.2	0.0	8.8	7.5	18.8	15.0	28.8
Jewell	2.0	3.4	13.0	16.6	20.5	26.6	28.0	36.6
Livermore	2.5	2.2	12.5	17.8	20.0	27.8	27.5	37.8
Manson	8.0	4.6	7.0	15.4	14.5	25.4	22.0	35.4
Moorland	3.0	2.0	12.0	18.0	19.5	28.0	27.0	38.0
Pocahontas	12.0	2.2	3.0	17.8	10.5	27.8	18.0	37.8
Pomeroy	10.0	3.1	5.0	16.9	12.5	26.9	20.0	36.9
Rockwell City	8.0	3.9	7.0	16.1	14.5	26.1	22.0	36.1
Rolfe	7.0	5.2	8.0	14.8	15.5	24.8	23.0	34.8
Tara	0.0	0.0	15.0	20.0	22.5	30.0	30.0	40.0
Vincent	4.0	4.4	11.0	15.6	18.5	25.6	26.0	35.6
Webster City	0.0	0.0	15.0	20.0	22.5	30.0	30.0	40.0
Williams	8.0	3.7	7.0	16.3	14.5	26.3	22.0	36.3

Table 14.

Estimated Total Investment and Annual Capital Recovery Cost of Constructing Grain Train Loading Facilities at Selected Potential Subterminal Sites Fort Dodge Area 1972 Costs by Size of Train.

Location	Size of Train					
	50-Car		80-Car		115-Car	
	Total	Annual*	Total	Annual*	Total	Annual*
Angus	$557,277	$90,128	$780,120	$127,142	$1,002,963	$164,151
Beaver	460,991	74,708	683,834	111,722	906,677	148,731
Blairsburg	478,136	76,156	700,979	113,170	923,822	150,179
Bode	475,548	75,948	698,391	113,061	921,234	149,971
Duncombe	536,129	86,505	758,972	123,518	981,815	160,528
Ellsworth	256,690	72,919	479,533	109,932	702,376	146,942
Farnhamville	493,349	78,823	716,192	115,836	939,035	152,846
Fonda	532,559	86,686	755,402	123,699	978,245	160,709
Gilmore City	537,117	86,604	759,960	123,618	982,803	160,627
Gowrie	612,889	99,983	835,732	136,997	1,058,575	174,006
Hardy	508,558	81,744	731,401	118,758	954,244	155,767
Havelock	526,364	85,228	749,207	122,241	972,050	159,251
Humboldt	512,238	81,780	735,081	118,794	957,924	155,803
Jefferson	297,852	47,574	576,708	94,430	799,551	131,439
Jewell	530,795	86,066	753,818	123,079	976,651	160,089
Livermore	551,769	89,563	774,612	126,576	997,455	163,586
Manson	449,715	76,786	672,558	113,800	895,401	150,809
Moorland	552,067	89,516	774,910	126,530	997,753	163,539
Pocahontas	459,547	72,284	682,390	109,297	905,233	146,307
Pomeroy	490,009	78,682	712,852	115,696	935,695	152,705
Rockwell City	478,794	76,715	701,637	113,729	924,480	150,738
Rolfe	445,740	76,459	668,583	113,472	891,426	150,482
Tara	612,889	99,983	835,732	136,997	1,058,575	174,006
Vincent	482,578	77,347	705,421	112,175	928,264	151,370
Webster City	612,889	99,983	835,732	136,997	1,058,575	174,006
Williams	475,291	75,938	698,134	112,952	920,977	149,961

* Includes annual insurance and taxes.

Transportation

This section describes the transportation system used in the Fort Dodge area to transport grain from farms to markets in 1971; and, presents alternative transportation systems for 1980. Maintenance costs for road and railways, operating costs for different modes of transportation, and a brief review of containerized and belt distribution systems are presented. Comparative energy requirements and the impact of truck movements on highways are also discussed.

Trucking costs

Various modes of transportation may be used to assemble the grain to elevators and distribute it to terminal markets. During the harvest months the grain fields are sometimes wet and it is often easier to assemble the grain by tractor-wagon or small farmer-owned trucks than by large trucks. During the peak harvest months of October and November much of the grain is moved from farms to local elevators in farmer-owned tractor-wagons or by 300-bushel trucks. Once harvesting pressures subside there is a greater incentive to use larger trucks capable of hauling greater distances than the tractor-wagon. In this study, it was assumed that during the peak harvest months farm tractors and 450-bushel wagons would be used to move grain from farms to elevators up to six miles. Grain hauled beyond six miles was moved in 300-bushel trucks. During non-harvest months, both 450-bushel trucks and tractor-wagons would be used. These assumptions are consistent with the actual types and sizes of vehicles which delivered grain to elevators in the Fort Dodge area in 1971 as shown in Table 15. These data were obtained from elevator questionnaires. It was assumed that grain trucked from elevators to subterminals or to final markets was hauled by 810-bushel tractor-trailer trucks.

Costs of operating tractor-wagons and various size trucks were estimated by a synthetic analysis of physical operations for the different vehicles. The cost of operating two 450-bushel wagons was estimated to be $0.0012 per bushel per mile. This estimate was based on each wagon traveling 1,000 miles per year and an average speed of 12 miles per hour. The wagons were assumed to have a life expectancy of 12 years. The only repair or maintenance required for the wagons was replacement of the tires at the end of six years. Wagons require no insurance or licensing fee. It was assumed that 12 percent of total tractor use was for grain shipment and only the variable costs of operating the tractor while hauling the grain were included.

The cost of operating a 300-bushel truck was estimated to be $0.0036 per

Table 15.
Estimated Grain Receipts at Country Elevators by Type of Delivery Vehicle, Fort Dodge Area 1970-71 Crop Year.

Type of Vehicle	Percent of Receipts
Farm Tractor and Wagon	38.8
Trucks of 300-bushel capacity or less	35.0
Trucks of 300-bushel capacity	26.2
Total	100.0

bushel per mile. The 300-bushel truck is used primarily on farms and it was assumed that the truck would travel 2,000 miles per year at an average speed of 20 miles per hour. Average maintenance and repair costs were estimated to be $90 per year.

It was assumed that the 450-bushel and 810 tractor-trailer trucks were owned and operated by independent truckers, farmers, or elevator operators. The cost of operating a 450-bushel truck was estimated to be $0.0008 per bushel per mile. The 810-bushel tractor-trailer truck was estimated to cost $0.0006 per bushel-mile. Assuming four trips per day, each truck would travel 55,000 miles per year.

The operating cost for an 810-bushel tractor-trailer truck operating long distances -- 400 miles per round trip at an average speed of 55 miles per hour -- was estimated to be $0.00037 per bushel per mile; this is equivalent to $0.30 per running mile.

Appendix D presents the operating costs of various size trucks and tractor-wagons. It was assumed that grain was hauled by independent truckers. Since there are no published rates by independent truckers, costs were used as a proxy for trucking rates in the solutions discussed in Chapter IV.

Barge costs and rates

Barge costs were estimated from Dubuque, Iowa, to New Orleans for April-November shipments. During the November-February period, the upper Mississippi River is frozen. However, the lower Mississippi is open from St. Louis south during the winter. Therefore, barge costs were also estimated from St. Louis to New Orleans.

The basic assumptions and estimates used in the analysis of barge costs were obtained from the president and vice president of a large barge company operating on the Mississippi River. The basic assumptions of the analysis are as follows:

1. The size of barge used in the analysis is the jumbo covered hopper barge with dimensions of 195' x 35' x 12'. The actual payload of this size barge depends on the draft of the river, the type of barge and the type of hatch cover. It was assumed that under normal Mississippi River conditions, the typical covered hopper barge payload would be 1,400 tons of grain.

2. Barges were assumed to encounter delays from congestion, waiting for tows, and other causes. The average speeds of travel were based on estimated actual rather than ideal operating conditions.
3. The distance from St. Louis to New Orleans was approximated at 1,050 miles. The New Orleans port region is about 100 miles long. Therefore, the actual distance depends upon the location of the elevator receiving the grain. The 1,050 miles is a somewhat arbitrary distance but realistic in the view of the executives of the company providing the estimates.
4. The towing costs were approximated by using towing charges per barge mile or per ton mile. The executives providing the data stated that these charges approximate the actual 1972 charges made on the river. Many of the tow boats are chartered and are used on multiproduct tows. It is therefore difficult to obtain good estimates of the cost of towing grain barges. The tow charges used in this study, in the opinion of the executives, reflect actual operating costs because of competition to obtain tows.
5. It was assumed that the covered hopper barges return empty from New Orleans. The executives took the position that barge backhauls do not pay on an incremental basis. The time lost waiting to get a backhaul is approximately 18-20 days. The additional revenue does not justify foregoing the revenue to be gained from a rapid return on the empty. The assumption would not hold during the period when the primary grain shipments would not be immediately available upon return to Dubuque.
6. Any repairs on the barges were assumed to be made in New Orleans while the barge was waiting for a return tow to St. Louis.
7. Insurance and administration costs vary substantially from firm to firm depending largely on the size of the operation. The costs used in this study were based on a larger operation. A smaller firm might have higher insurance costs and lower administrative costs. The specific cost estimates are presented in Table 16. The procedure for estimating these costs are found in Appendix E.

Grain hauled by barges is an exempt commodity. Therefore, barge rates fluctuate with supply and demand for barges. However, barge rates are published by the Waterways Freight Bureau. The rates used in this

Table 16.

Estimated Costs of Shipping Corn and Soybeans by Barge from Dubuque and St. Louis to New Orleans in Cents per Bushel, 1972.

	Corn	Soybeans
Dubuque to New Orleans	11.76	12.60
St. Louis to New Orleans	7.63	8.18

study were taken from Supplement 41 to Freight Tariff 7, Waterways Freight Bureau. The published barge rates on grain were $4.91 per ton on grain from Dubuque to New Orleans and $3.25 per ton from St. Louis to New Orleans. While actual rates have fluctuated from 50 to 200 percent of tariff in recent years, for this study it was assumed that barge rates were 100 percent of tariff.

Rail rates and costs

The rail tariffs available in the Fort Dodge area until the summer of 1971 were all single car rates. The single-car rate is often referred to as a random car rate because one or more cars may be shipped randomly at the discretion of the shipper. Following the summer of 1971, multiple-car tariffs were issued for 27- and 54-car export rates to Houston, Texas. This tariff was followed by 25- and 50-car export rates to Chicago and New Orleans and one railroad offered a special export rate to the Gulf if three or more cars were shipped as a unit. The 50-car trains might be called occasional trains because the tariffs require a minimum of five consecutive shipments from a subterminal.

Actual rail rates for shipping corn and soybeans during 1972 were used to analyze the economics of grain distribution in the Fort Dodge area. Various tariffs were examined and the lowest published rates from elevators in the Fort Dodge area to each market were selected. Single-car rates for intrastate movements were obtained from a published mileage rate tariff. If soybean rates were not available, it was assumed that the rate for shipping soybeans, adjusted for weight differences, was the same as corn.

In this study, all elevators with access to a rail line, regardless of the carrying capacity of the line, had the option of using the single-car rate. The multiple-car rates were restricted to elevators or subterminals located on heavy rail lines since these rates require the grain to be shipped in fully loaded jumbo covered hopper cars. The three-car rate to New Orleans was made available to all elevators located on the lines of the railroad which published this rate. The 50-car rate to export markets at Chicago, Milwaukee, New Orleans, and Houston was made available to the 26 potential subterminal sites and to four subterminal sites located adjacent to, but outside of the area studied. A rate, published for East Central Illinois shippers for grain moving to the Gulf was also made available to the potential subterminal sites in the Fort Dodge area. This is a guaranteed volume rate requiring the shipper to move 517,500 tons or approximately 18 million bushels of grain per year to the Gulf in continuous trains of not less than 115 shipper owned or leased jumbo covered hopper cars. This rate is presently available to shippers in the Champaign, Illinois, area which is located approximately 800 miles to New Orleans. The Fort Dodge area is approximately 1,200 rail miles from New Orleans. The actual Champaign-New Orleans rate was multiplied by 1.5 to account for the additional distance from Fort Dodge. In addition, the cost of leasing 138 new jumbo covered hopper cars was added to the rate. It was assumed that additional cars would be needed to keep the train running constantly on an annual basis. Table 17 compares the transportation rates for shipping corn from Fort Dodge to New Orleans for various sizes of rail shipments and for truck-barge and rail-barge combinations.

One objective of the present study is to estimate the cost of transporting corn and soybeans to the markets served by country elevators located within the Fort Dodge area by different sizes of rail shipments.

These costs were estimated by using the 1969 Interstate Commerce Commission Cost Scales. The detailed procedure for estimating these rail costs is presented in Appendix F. Table 18 compares the estimated variable and fully allocated costs of shipping corn in box and hopper cars from Fort Dodge, Iowa to various markets for various size shipments. These sizes include single-car, 3- to 10-car assembled into a 50-car unit moving to a single destination, 50-car, and 115-car consignments. The costs are expressed in terms of cents per bushel. The published rates are also presented for comparison with the estimated costs.

The published single-car rates to Omaha, Kansas City, Pekin, St. Louis, and Seattle include in-transit privilege. The cost of this privilege was estimated to be 7.0 cents and 4.1 cents per bushel for corn in box and hopper cars, respectively. To improve the comparability of the published rates and estimated rail costs, the estimated cost of transit has been added to the estimated variable and fully allocated cost to those markets which have in-transit privileges included in the rates.

The data in Table 18 indicate that the estimated single-car variable cost is substantially higher for box car shipments than for hopper car shipments. A

Table 17.

Transportation Rates for Moving Corn from Fort Dodge to New Orleans by Mode in Cents per Bushel, 1972.

Mode	Cents per bushel
Single Car Export	25.76
3 Car	23.52
25 Car Consignment	23.52
50 Car Consignment	21.84
115 Car Guaranteed Volume	17.00
Truck-barge (1) March-November (2)	37.57
Truck-barge December-February (3)	42.33
Rail-barge March-November (2)	27.30
Rail-barge December-February (3)	37.52

(1) Barge rates were computed at 100 percent of tariff.
(2) Fort Dodge to Dubuque to New Orleans.
(3) Fort Dodge to St. Louis to New Orleans.

Table 18

Estimated Variable and Fully Allocated Costs of Shipping Corn in Box and Hopper Cars from Fort Dodge, Iowa, to Selected Markets by Size of Shipment and Published Rates in Cents per Bushel, 1972

Shipment size	Market	Published rate	Estimated Cost: Variable box	Variable hopper	Fully Allocated box	Fully Allocated hopper
Single-Car	Omaha	13.44	16.70	10.25	18.44	11.98
	Kansas City	18.76	20.09	13.17	22.74	15.82
	Pekin	19.32	21.65	14.44	24.63	17.42
	Chicago	14.00	14.51	10.17	17.51	13.18
	Milwaukee	14.00	16.51	11.89	19.98	15.36
	St. Louis	22.12	23.95	16.46	27.74	20.24
	Gulf	25.76	33.61	26.15	40.92	33.45
	Seattle	84.84	54.11	41.87	66.76	54.53
3- to 10-Car	Gulf (1)	23.52	--	23.53	--	29.87
	Seattle (2)	38.92	--	37.59	--	49.26
50-Car	Chicago	12.04	--	8.75	--	11.58
	Milwaukee	12.04	--	10.23	--	13.48
	Gulf	21.84	--	22.34	--	28.68
115-Car	Gulf (3)	17.00	--	18.74	--	23.86

(1) This is the published 3-car rate.
(2) This is the published 5-car rate.
(3) As indicated in a previous section, this rate is not presently available to stations in Iowa; the rate shown has been estimated from a published rate available to Illinois stations.

comparison of costs with rates shows that box car variable costs exceed single-car rates from Fort Dodge to all markets except Seattle while variable hopper car costs exceed rates only to the Gulf. Fully allocated box car costs exceed the rates to all markets except Seattle, whereas fully allocated hopper car costs are less than rates to all markets except Milwaukee and the Gulf. The 3- to 10-car rate covers variable cost to both markets considered and the 50-car rate covers variable cost to Chicago and Milwaukee. However, the only multiple-car rate covering estimated fully allocated cost is the 50-car rate to Chicago.

Table 18 also shows the differences among the published rates and the estimated cost differentials for various shipment sizes from Fort Dodge to the Gulf. For example, the single-car rate is 25.76, while the three-car rate is 23.52 cents per bushel: the three-car rate offers the shipper a per bushel saving of 2.24 cents over the single-car rate. Similarily, the 50-car rate offers a 1.68-cent per bushel saving over the three-car rate, while the 115-car rate offers a 4.84-cent saving over the 50-car rate. The variable and fully allocated cost progessions, as calculated, can be seen to be quite consistent with the rate differentials.

The estimated variable costs, rather than the fully allocated costs, were used in the analysis in this study. Economists generally agree that, since fully allocated costs are computed with an arbitrary allocation of fixed costs to units of traffic, it is meaningless as a basis for the pricing of rail service and must be rejected as the test for a particular rail rate. Variable cost, although not to be employed for the determination of a rail rate--specifies the lower boundary for a pricing decision. The railroad must determine a certain level over variable cost at which the established rate generates a maximum contribution toward fixed cost and the railroad's net income.

The Interstate Commerce Commission shares this same position, as is indicated in the following statement related to the use of variable cost in the process of ratemaking:

> We further find that "variable costs" when appropriately determined may be utilized as indicative of the minimum level of expenses which must normally be recovered by a carrier in providing particular services.

In this study, the variable rail costs are compared with truck and barge costs. For a valid comparison, the three sets of costs should be computed on a comparable basis. As computed for this study, the truck costs, other than the costs of the tractor and trailer, are essentially 100 percent variable with the volume of traffic. The barge costs, other than the cost of the barge, are also essentially 100 percent variable with the volume of traffic. The variable rail costs, other than the cost of the cars, are variable with the volume of traffic, given the assumptions of the Interstate Commerce Commission Cost Scales. The estimated constant rail costs are an approximation to the constant costs associated with railroads. Thus, conceptually, the truck and barge cost and the variable rail costs as computed in this study are basically comparable costs.

The major difference between the barge costs and the variable rail costs is an estimated $0.86 per thousand gross ton-mile for railroad right-of-way maintenance. For example, the variable cost of moving grain in a loaded covered hopper car from Fort Dodge to New Orleans includes 9.2 cents per hundred-weight for maintenance of way. Similarly, the distinction between the barge and truck costs is the $1,260 per year license fee and 3 cents per running mile federal and state fuel tax borne by truckers; the fuel tax is allocated to roadway maintenance. The barge costs include no provision for maintenance of way.

Table 19 compares the estimated cost of moving corn from Fort Dodge to New Orleans by mode. The cost differential between single hopper and 3- to 10-car shipments is 2.6 cents per bushel. The estimated cost saving of a 50-car shipment over a single hopper is 3.8 cents per bushel, and an estimated additional 3.0 cents per bushel is saved by shipping in an 80-car continuous train rather than a 50-car randomly-scheduled train.

Comparing the intermodal combinations, moving grain from Fort Dodge to New Orleans by rail-barge is less costly than by truck-barge, regardless of season. Winter month movements by rail-barge are more costly than movements during the summer months. Belt-barge is the most expensive mode.

A comparison of the rail versus intermodal combinations shows truck-barge costs from Fort Dodge to New Orleans to be less than single box car consignments: the differential is 3.9 cents per bushel in the summer months and 0.8 cents per bushel during the winter. However, the same movement in a hopper car is less costly than truck-barge. Hopper car variable costs are 3.6 cents per bushel less

Table 19.

Estimated Variable Costs of Moving Corn from Fort Dodge to New Orleans by Mode in Cents per Bushel, 1972.

Mode			Cents per Bushel
Rail			
Single box car			33.61
Single hopper car			26.15
3- to 10-car units in one train			23.53
50-car train			22.34
80-car train (continuous)			19.34
115-car train (continuous)			18.74
Intermodal Combinations			
Truck-barge	March-November (1)		29.70
Truck-barge	December-February (2)		32.77
Rail-barge	March-November (1)	box	27.62
		hopper	23.71
Rail-barge	December-February (2)	box	28.43
		hopper	23.84
Belt-barge	March-November (1)		36.96

(1) Fort Dodge to Dubuque to New Orleans.
(2) Fort Dodge to St. Louis to New Orleans.

than truck-barge in the summer and 6.6 cents less in the winter. On the other hand, the cost advantage favors rail-barge shipments over single-car rail: rail-barge has a 6.0 and 5.2 cents per bushel advantage in the summer and winter over single box car shipments. Rail-barge has a 2.4 and 2.3 cents per bushel advantage during the summer and winter months, respectively, over single hopper car shipments. Finally, all multiple-car shipments from Fort Dodge to New Orleans are less costly than truck-barge or rail-barge. In summary, the rail-barge mode has a cost advantage over single-car shipments from Fort Dodge to New Orleans, whereas multiple-car shipments are less costly than rail-barge.

For shipments from Fort Dodge to markets other than New Orleans, the choice of mode is between rail and truck. For example, for moving corn to Dubuque, Iowa, the estimated rail cost is 12.01 and 8.10 cents per bushel for a single box and hopper car, respectively, while the estimated truck cost is 14.26 cents per bushel.

Containerized and beltline systems

In addition to the traditional means of transporting grain by rail and truck, other methods of grain transportation are possible. Transporting grain by containers or by belts are two methods that are presently being proposed or tried.

A containerized grain distribution system involves loading a container with grain either at the point of production or at an assembly point and then transporting the container by truck, rail, barge, or any truck-rail-barge combination to a final destination. In 1973, a grain firm in Marcus, Iowa, shipped food soybeans in containers holding 600 bushels from Marcus, Iowa, by truck to Sioux City, Iowa, a distance of 45 miles. In Sioux City, the grain containers were transferred from the trucks and loaded on flat rail cars to be transported to the West Coast. Special permits, however, were required and specific routes were specified by the Iowa Highway Commission for the trucking firm to transport the containers because the legal maximum weight for axle loads was exceeded. The shipper has concluded that the greatest potential for containers appears to be in moving high value specialty grain products, such as food soybeans. However, it was his judgement that it was less costly to move the soybeans by rail hopper car and to segregate the beans in a special hold in the ship.

A system has been proposed to move grain from North Central Iowa to McGregor, Iowa by belt. The grain would then be transferred into barges for movement down the Mississippi River. The cost of the system as estimated by the proposing firm is:

	Cost in cents per bushel
Investment	10.3
Finance	10.5
Maintenance and operation	4.4
Total	25.2

To move the grain to New Orleans would require the additional cost of barging the grain from McGregor, Iowa, to New Orleans.

Rail system

Four rail companies operate in the Fort Dodge area. The rail companies include the Chicago and North Western (C&NW); Chicago, Milwaukee, St. Paul and Pacific (CMSP&P); Chicago, Rock Island and Pacific (CRI&P); and the Illinois Central Gulf (ICG).

The rail network serving the Fort Dodge area in 1971 is presented in Figure 1. Within the area there were 702 miles of track. Of the 702 miles of line only 43.9 percent, or 308 miles, of the existing track was of sufficient grade and quality to handle fully loaded, 100-ton hopper cars. The remaining 394 miles of rail line or 56.1 percent had a carrying capacity of less than 263,000 pounds and, thus, were not capable of carrying loaded 100-ton covered hopper cars. Rail lines were classified as heavy lines if the rail line could handle loaded covered hopper cars. Otherwise, the lines were classified as light rail lines.

Rail upgrading costs

The cost of upgrading the light lines to lines capable of handling loaded covered jumbo hopper cars at a 35-40 mile per hour speed limit depends upon many factors. The condition of the roadbed and cross ties, the weight of the rail, and the number of bridges or roads the line crosses are a few of the factors that influence the cost of upgrading a branch rail line. For most of the light branch rail lines in the Fort Dodge area, upgrading to handle loaded jumbo hopper cars would include replacing the 60-70-pound rail with 90-pound rail, and replacing

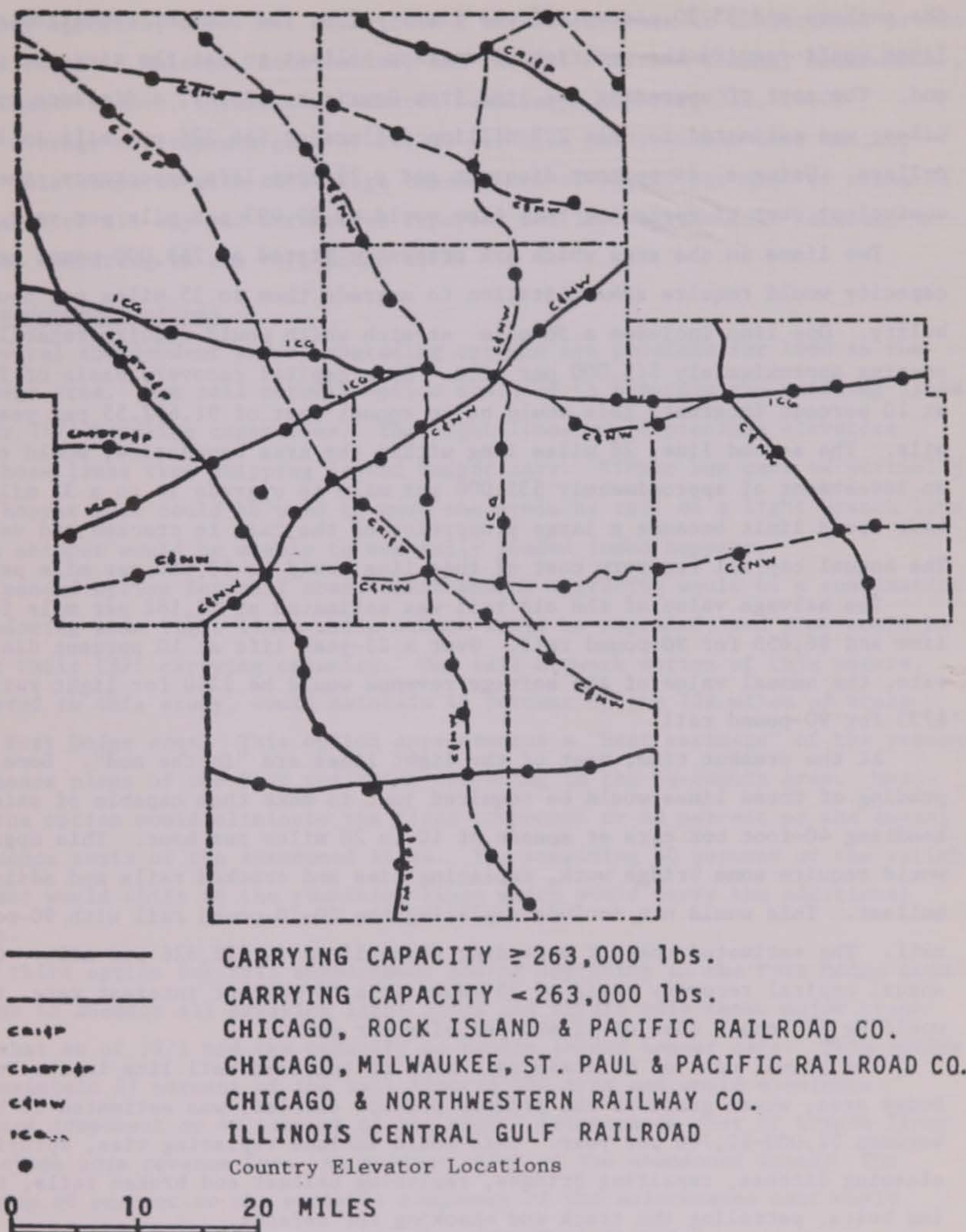


Figure 1.

Location of the rail line system and country elevators, Fort Dodge Area, 1971.

the anchors and 35-50 percent of the ties. Also, the present condition of the lines would require the addition of surface ballast to get the ties out of the mud. The cost of upgrading the line from Gowrie to Sibley, a distance of 54 miles, was estimated to cost 2.5 million dollars or $46,296 per mile in 1972 dollars. Using a 10 percent discount and a 25-year life expectancy, the annual equivalent cost of upgrading this line would be $5,093 per mile per year.

Two lines in the area which are presently listed as 263,000-pound weight capacity would require rehabilitation to upgrade them to 35 miles per hour capability. One line includes a 56-mile stretch which would require rehabilitation costing approximately $15,000 per mile. On a capital recovery basis of 25 years at 10 percent interest, this would be an annual cost of $1,652.55 per year per mile. The second line, 28 miles long within the area boundaries, would require an investment of approximately $35,000 per mile to upgrade it to a 35 mile per hour speed limit because a large proportion of the rail is cracked and very old. The annual capital recovery cost of this line would be $3,860 per mile per year.

The salvage value of the old rail was estimated at $2,182 per mile for light line and $6,653 for 90-pound rail. Over a 25-year life at 10 percent discount rate, the annual value of the salvage revenue would be $240 for light rail and $733 for 90-pound rail.

At the present time, most of the light lines are "in the mud". Some upgrading of these lines would be required just to make them capable of safely handling 40-foot box cars at speeds of 10 to 20 miles per hour. This upgrading would require some bridge work, replacing ties and cracked rails and adding ballast. This would not include replacing the 60-70-pound rail with 90-pound rail. The estimated cost of upgrading these lines is $22,626 per mile. On an annual capital recovery basis of 25 years at a 10 percent interest rate, this would be an annual cost of $2,493 per mile per year.

The annual cost of maintaining a mile of upgraded rail line in the Fort Dodge area, where grain is the primary product carried, was estimated to be between $2,000-$2,700 per year. This would include replacing ties, spraying, cleaning ditches, repairing bridges, replacing ballast and broken rails, tightening bolts, patroling the track and checking for defects.

The annual property tax was excluded from the annual cost of maintaining a branch rail line because the tax is ad valorem in nature and, as ruled by regulatory agencies, does "not constitute a savable expense in abandonment proceedings" as found in Chicago, Rock Island, and Pacific Railroad Company Abandonment, Horton Kansas Branch, Interstate Commerce Commission Reports, 312, 1960.

An average maintenance cost of $2,350 per mile per year was used in this study. This compares with an average expenditure of $5,220 per mile of track on maintenance of all way and structures reported for 1971 by the four railroad companies operating in the Fort Dodge area.

Rail abandonment options

Several abandonment and/or upgrading options are possible for 1980 in the Fort Dodge area. One rail network option would be to maintain the existing lines at their 1971 handling capacities. The light lines would preclude elevators using those lines from shipping loaded hopper cars. Either box cars or partially loaded hopper cars could be used to move the grain by rail on a light branch line, but the shipper would be unable to use fully loaded jumbo hoppers.

A second option for rail abandonment and/or upgrading would be a combination of abandoning some light lines while others would be upgraded; and some could be left at their 1971 carrying capacity. One rail network option of this nature, considered in this study, would maintain 46 percent of the 702 miles of track in the Fort Dodge area. This option approximates a "best estimate" of the present maintenance plans of the four railroads operating in the 6½-county area. Moreover, the option would eliminate the fixed component or 40 percent of the annual maintenance costs of the abandoned lines. The remaining 60 percent or the variable component would shift to the remaining lines which would carry the additional traffic.

A third option for rail abandonment and/or upgrading in the Fort Dodge area would be to abandon all existing light lines and retain only those major trunk lines that as of 1971 had the capacity to handle loaded hopper cars. This option would maintain 27 percent of the rail line in the area and would eliminate the fixed component or 40 percent of the annual maintenance cost of branch lines and provide some revenue from the salvage value of the abandoned lines. The remaining 60 percent or the variable component of the maintenance cost would shift to the remaining lines carrying the additional traffic.

A fourth option would be to upgrade all light branch lines to handle jumbo hopper cars. This option would provide all elevators the opportunity of shipping grain in multiple hopper car shipments with the corresponding lower shipping rates per bushel mile. Offsetting the lower rate advantage from this option, are the costs that are necessary for upgrading the branch rail lines and expanding elevator load-out facilities. These four rail network options are delineated by Figures 2, 3, 4 and 5.

Shipping patterns

It was not possible to specify demand functions for the quantity of grain to be received by the specific final markets. Therefore, it was necessary to substitute predetermined monthly shipping patterns to allocate grain to markets over the 12 months of a year. Two alternative shipping patterns were specified. The first alternative is a constant shipping pattern that requires that same quantity of grain be shipped out of the area each month. The second alternative is based on actual monthly rail shipments from the Fort Dodge area during the October 1970 - September 1971 period. These two alternatives are presented in Table 20.

Road system

In 1971 there were 6,812 miles of rural roadway in the Fort Dodge area. All roads in the Fort Dodge area were classified by six surface types of road, which include: interstate rigid, other primary rigid, high flexible, intermediate flexible, surface treated flexible, and secondary unpaved.

Interstate rigid includes all interstate portland concrete cement paved roads. Other primary rigid includes all primary portland concrete cement paved roads. High flexible includes secondary portland concrete cement paved roads. Intermediate flexible includes all asphalt concrete paved roads. Surface treated flexible includes secondary low type bituminous surfaced roads. Secondary unpaved includes all dirt and gravel surfaced roads. The road network in the Fort Dodge area during 1971 is presented in Figure 6. The changes in the 1971 road network by 1980 as planned by the Iowa Highway Commission are presented in Figure 7. Most of the surface treated flexible pavements are under the supervision of county governments. These roads receive substantial damage from heavy truck movements and are extremely expensive to resurface and maintain. Individual counties with the encouragement of the Iowa Highway Commission are currently upgrading this road type. Therefore, in addition to the Iowa Highway Commission plans for 1980, it was assumed that 66 percent, 74 miles, of surface treated flexible pavement would be upgraded to intermediate flexible pavement by 1980.

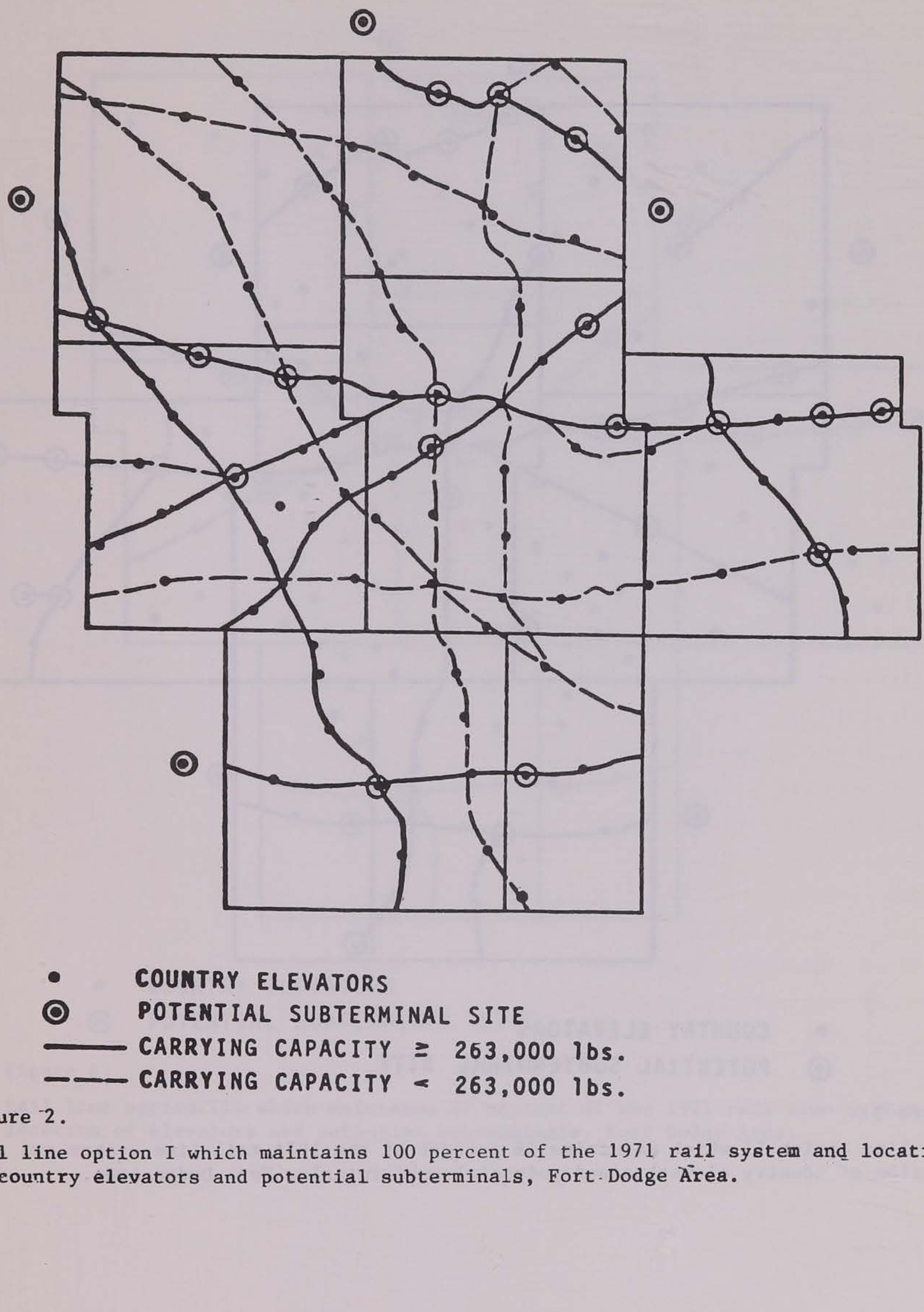
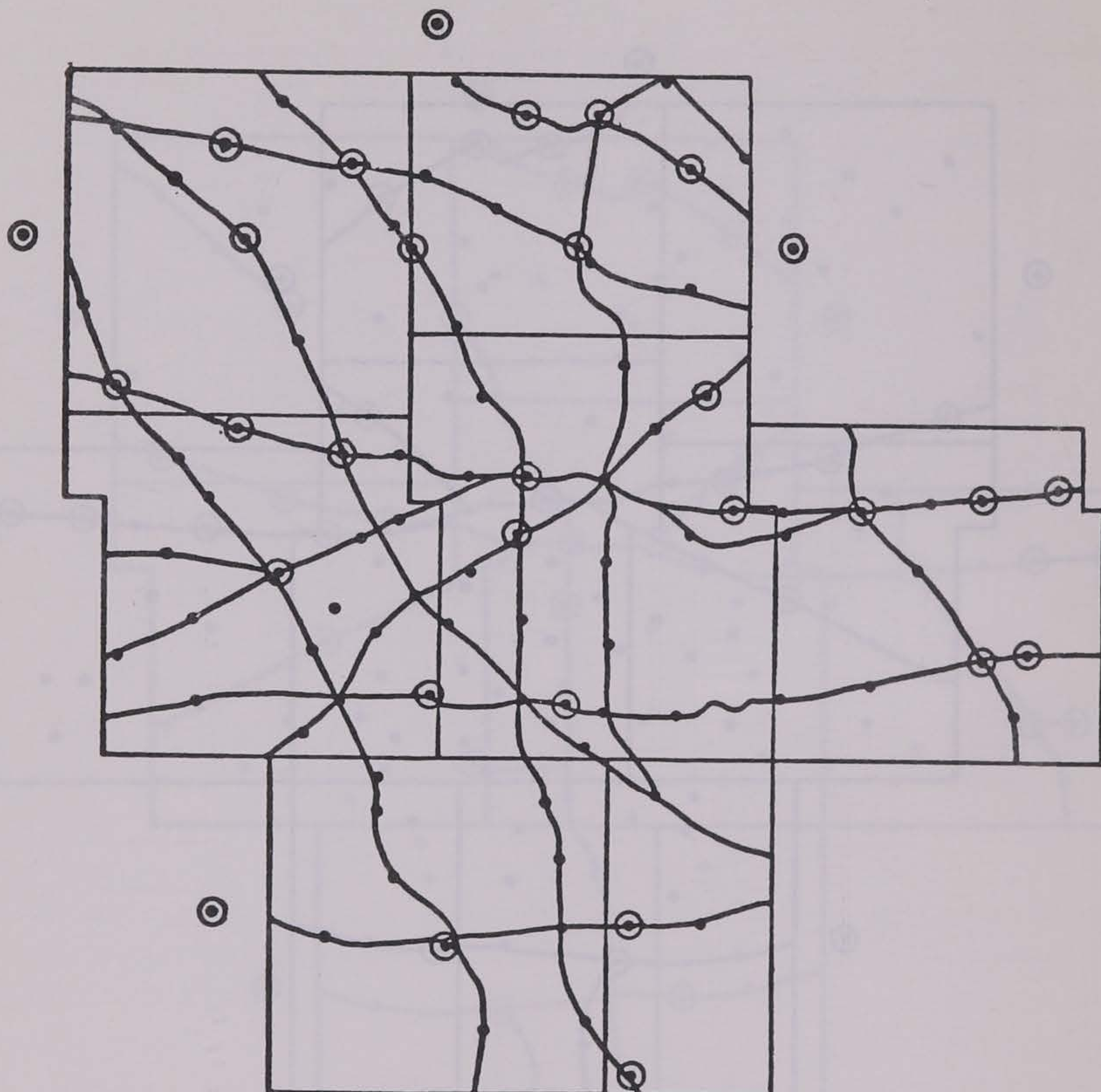


Figure 2.

Rail line option I which maintains 100 percent of the 1971 rail system and location of country elevators and potential subterminals, Fort Dodge Area.



• COUNTRY ELEVATORS

◎ POTENTIAL SUBTERMINAL SITE

Figure 5.

Rail line option IV which upgrades all light lines in the 1971 rail system and location of country elevators and potential subterminals, Fort Dodge Area.

Table 20.

Specified Monthly Percentage Distribution of Corn and Soybean Shipments from Elevators and Subterminals to Final Markets.

Month	Constant Pattern	Actual Pattern
October	8.3	4.8
November	8.3	5.3
December	8.3	4.0
January	8.3	7.3
February	8.3	5.8
March	8.3	8.3
April	8.3	7.6
May	8.3	11.5
June	8.3	6.2
July	8.3	14.7
August	8.3	10.0
September	8.3	4.5

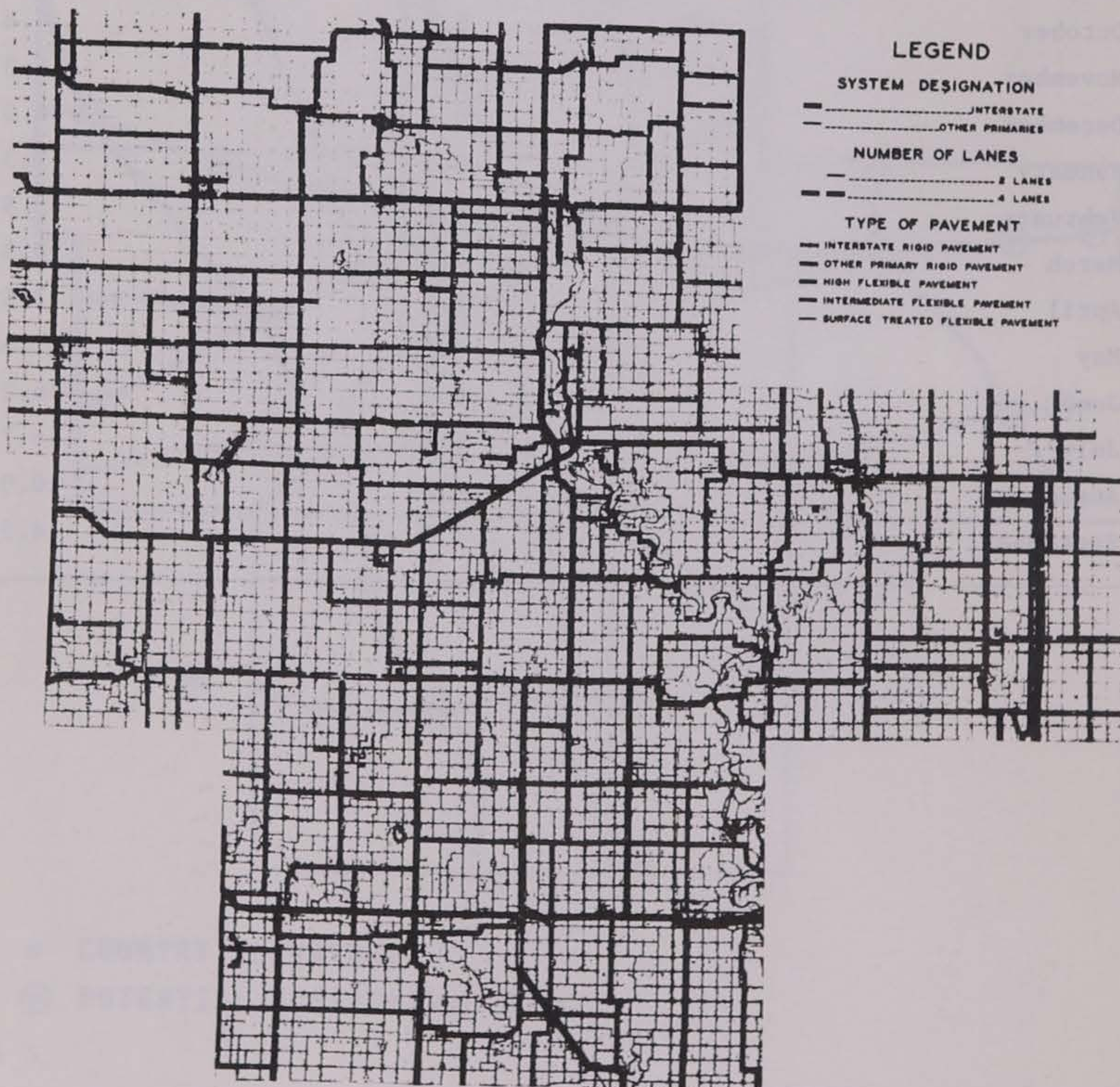


Figure 6.

1971 Primary Highway Facilities for the Fort Dodge Area.

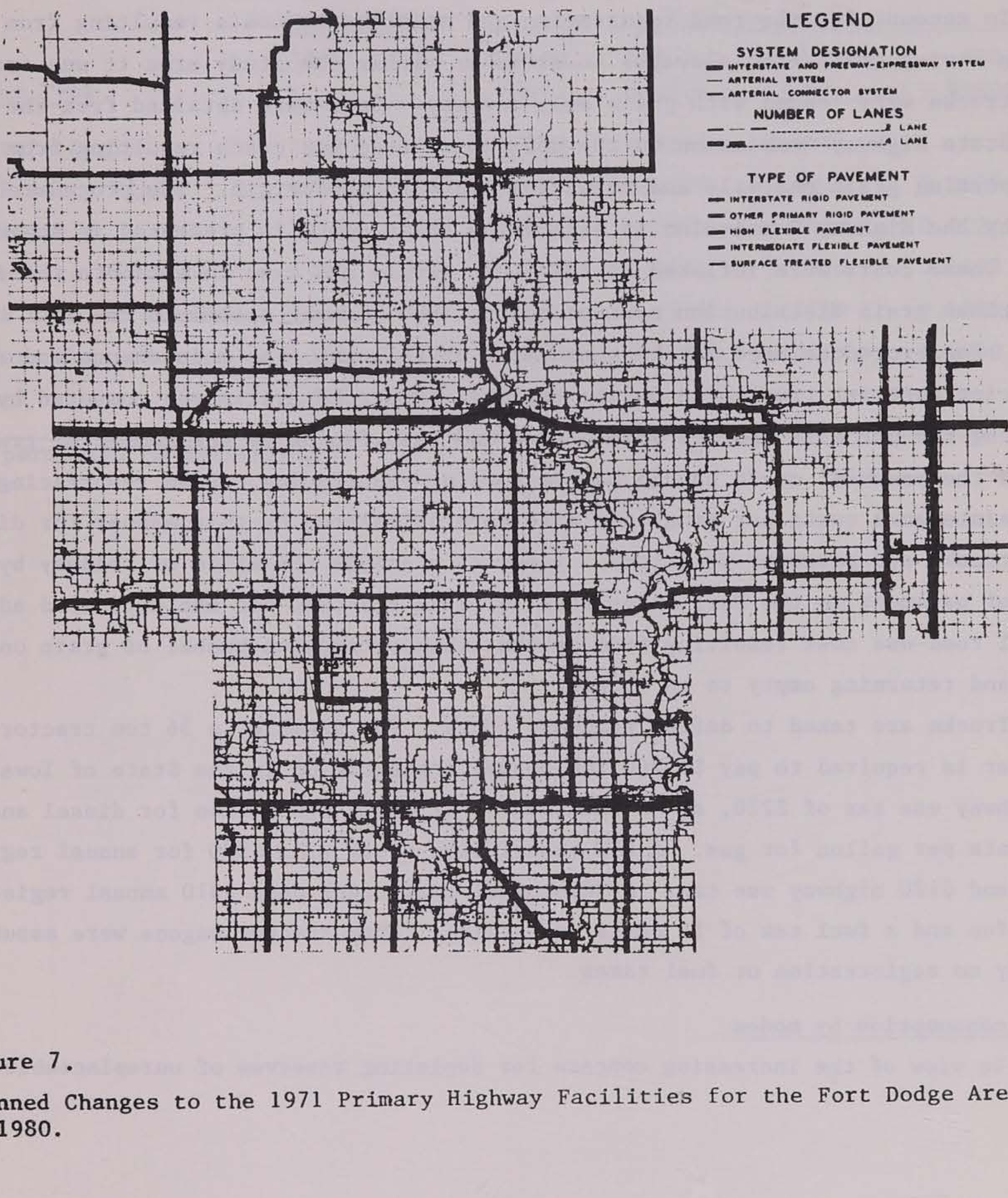


Figure 7.

Planned Changes to the 1971 Primary Highway Facilities for the Fort Dodge Area by 1980.

Road maintenance and resurfacing costs

For this report it was assumed that resurfacing and maintenance costs for road surface and structures depend primarily on road use. Each of the six road pavement classifications represent various road structures, and each pavement structure can withstand only a certain number of truck loads before resurfacing and/or maintenance is required.

To account for the road resurfacing and maintenance costs resulting from trucks moving grain from elevator to elevator within the study area it was assumed that trucks were loaded with grain only one way. Data were obtained from the Iowa State Highway Commission on the additional road use costs resulting from transporting grain one mile and returning empty to the origin. The procedure used by the Highway Commission in estimating these costs is presented in Appendix G. These costs were inflated to 1972 cost levels and used to estimate the impact of various grain distribution systems on the 1980 highway system in the Fort Dodge area. The procedure used may be summarized as follows: the maintenance and resurfacing cost per truck-mile on the expected 1980 road system was computed by dividing the per mile cost of maintenance and resurfacing by the number of truck passes the pavement could handle before needing resurfacing. Road resurfacing and maintenance costs per truck per mile were calculated by this manner for different size trucks and pavement structure. Table 21 presents the miles of roadway by type of pavement in the Fort Dodge area for 1972 and 1980 and the estimated additional road-use cost resulting from trucks transporting one bushel of grain one mile and returning empty to an origin.

Trucks are taxed to defray road-use costs. For example, a 36 ton tractor-trailer is required to pay $1,260 for annual registration in the State of Iowa, a highway use tax of $220, and a fuel tax of 12 cents per gallon for diesel and 11 cents per gallon for gas. A 450-bushel size truck paid $590 for annual registration and $120 highway use tax. A 300-bushel size truck paid $310 annual registration fee and a fuel tax of 11 cents per gallon. Farm tractor wagons were assumed to pay no registration or fuel taxes.

Fuel consumption by modes

In view of the increasing concern for depleting reserves of unreplaceable

Table 21.

1972 and Estimated 1980 Number of Rural Highway Miles and Estimated Additional Highway Resurfacing and Maintenance Cost in Cents per Bushel per Round Trip Mile by Type of Vehicle and Pavement, Fort Dodge Area.

	Road Miles		Type of Truck			
Pavement Type	1972	1980	810-Bu. Semi.	450-Bu. Tandem	300-Bu. Truck	2 - 450-Bu. Wagons
Interstate Rigid	23	31	0.0006	0.0005	0.0007	*
Other Primary Rigid	249	326	0.0010	0.0009	0.0013	0.0009
High Flexible	439	439	0.0030	0.0024	0.0108	0.0026
Intermediate Flexible	799	855	0.0175	0.0142	0.0626	0.0153
Surface Treated Flexible	112	38	0.2142	0.1739	0.2559	0.1881
Secondary Unpaved	5,190	5,190	0.0056	0.0099	0.0149	0.0050
Total	6,812	6,879				

* Not permitted on Interstate.

energy sources, there is interest in the impact of alternative transportation systems on fuel consumption.

The purpose of this analysis is to describe a procedure used to evaluate the fuel requirements of alternative modes of grain transportation. The fuel consumption coefficients measured in gallons of diesel fuel per net ton mile for each mode include the fuel consumption for an empty backhaul. They do not include the fuel attributable to switching operations and non-routine operations within any mode.

Barge

The fuel consumption for grain movements by barge were based on estimates obtained from a large barge company operating on the Mississippi River for barge shipments from Dubuque to New Orleans. The average fuel consumption per day for a tow of loaded barges going downstream was assumed to be equal to the average fuel consumption per day for a tow of empty barges going upstream against the current. The following conditions were assumed to exist in a barge shipment from Dubuque and St. Louis to New Orleans.

1. Dubuque to St. Louis

   Assume a 3,200-horsepower towboat which uses 2,800 gallons of fuel per day on a locking river and requires 6.6 days for the 800-mile round trip. Further, it was assumed that the downstream trip included 10 loaded barges at 1,400 net tons per barge and the ratio of round trip miles to net cargo miles was 2 to 1.

2. St. Louis to New Orleans

   Assume a 7,500-horsepower towboat which uses 7,500 gallons of fuel per day on a non-locking river and requires 14.9 days per 2,100-mile round trip. The downstream trip was assumed to include 35 loaded barges at 1,400 net tons per barge and the ratio of round trip to net cargo miles is 2 to 1.

The following procedure was used to estimate the gallons of fuel per net ton-mile of grain hauled:

Dubuque to New Orleans:

Gallons per net ton-mile =

$$\frac{\left(\frac{2{,}800 \text{ gallons}}{1 \text{ day}}\right)\left(\frac{6.6 \text{ days}}{800 \text{ miles}}\right) + \left(\frac{7{,}500 \text{ gallons}}{1 \text{ day}}\right)\left(\frac{14.9 \text{ days}}{2{,}100 \text{ miles}}\right)}{(14{,}000 \text{ net tons} + 49{,}000 \text{ net tons})} = .0024 .$$

St. Louis to New Orleans:

Gallons per net ton mile =

$$\frac{\left(\frac{7{,}500 \text{ gallons}}{1 \text{ day}}\right)\left(\frac{14.9 \text{ days}}{2{,}100 \text{ miles}}\right)(2)}{(49{,}000 \text{ net tons})} = .0022.$$

Rail

A 3,000 H.P. locomotive unit per 2,000 gross tons was assumed. Each 2,000 gross tons was assumed to include 160 tons for the locomotive, a total tare weight of 462 tons for approximately 14.2 hopper cars and 1,385 net tons of grain. Assuming an empty backhaul, the ratio of gross ton-miles to net ton-miles is 2,622 gross ton-miles to 1,385 net ton-miles. An average load factor of 0.65 was assumed and an average speed of 35 miles per hour. The average fuel consumption of 0.058 gallons per horsepower-hour is based on the same use cycle as the load factor.

$$\left[\frac{(3{,}000 \text{ H.P.}) \quad (0.65)}{(2{,}000 \text{ gross tons}) \quad (35 \text{ mph.})}\right]\left[\frac{2{,}622 \text{ gross ton-miles}}{1{,}385 \text{ net ton-miles}}\right]\left[\frac{0.058 \text{ gallons}}{\text{horsepower-hours}}\right] =$$

.0030 gallons per net ton-mile.

Truck

The average fuel consumption per round trip mile for a tractor-trailer combination was assumed to be one gallon for four miles. An average cargo of 24 net tons per round trip was assumed. The ratio of round trip miles to net cargo miles is 2 to 1.

$$\left[\frac{(1 \text{ gallon})}{(4 \text{ miles}) \quad (24 \text{ net tons})}\right]\left[\frac{2 \text{ miles}}{1 \text{ mile}}\right] = .0208 \text{ gallons per net ton-mile}.$$

Chapter IV
Results

Alternative grain distribution systems were evaluated by comparing the maximum joint net revenue for various distribution systems and rail line networks using projected 1980 grain volumes. Net joint income was defined as the gross income from the sale of the projected 1980 volume of 118 million bushels of grain delivered to one or more of eleven markets, minus all transportation from farm to market, non-farm storage, variable handling and facility investment costs and rail line maintenance and upgrading costs. Transportation alternatives considered included the traditional single-car rail system and various combinations of multiple rail car shipments of 3 to 10 cars, 50, 80, and 115 cars, truck-barge, and rail-barge.

Computer programs were developed to determine the most efficient system of grain distribution. Data required in the programs include the 118 million bushels of grain expected to be sold outside of the area in 1980 along with prices from the eleven markets now served by the area, as well as handling costs and transportation rates which are presently available in Iowa or Illinois and the rail line options. The computer solutions determined what marketing and shipping system would produce the most net joint revenue for the 6½ counties, using various combinations of all these alternatives. For each distribution system and rail line network option, the optimal number, size, and location of assembly and shipping plants were determined. Increasing the number of plants lowers the cost of grain assembly and distribution, but increases capital requirements of the additional plants. Increasing the size of the shipment reduces the number of shipping plants and the size of the rail network.

Alternative rail line systems vary in cost to upgrade and maintain. A rail line network with a high line density is more costly to upgrade and maintain than a system with relatively fewer lines. A rail system with many heavy rail lines, however, provides more potential subterminal sites than a rail system with only a few main rail lines. Thus, in addition to the investment requirements resulting from increasing the number of subterminals, the transportation savings were also balanced against the costs of upgrading and maintaining the rail lines necessary to sustain the additional plants.

Traditional single-car system

To provide a benchmark with which to evaluate alternative distribution systems, total joint net revenue was estimated for the traditional single-car system. This system which existed in Iowa until 1971, consisted of farmers delivering grain to the local country elevators. These elevators in turn, shipped the grain to various markets in single rail cars or trucks on a random basis. Box cars were loaded at elevators located on light rail lines and either box or covered hopper cars were loaded at elevators located on heavy lines.

In the evaluation of this system, all 1971 rail lines were permitted to remain in existence at their 1971 weight carrying capacity. A charge of $2,350 per mile per year was made for rail line maintenance. In addition, an annual cost of $2,493 per mile per year was charged to rehabilitate the light rail lines. The projected 1980 volume of 118 million bushels of grain was shipped on the actual 1970-71 monthly shipping pattern on 1971-72 single-car rail rates, barge rates and estimated trucking costs. Grain was allocated among the eleven markets on the basis of 1969-70 crop year prices.

Total joint net revenue from this system would have been $174,209,000 for the projected 118 million bushels of corn and soybeans. This consisted of $177,003,000 total revenue net of all farm to market transportation and handling costs. Then $2,794,000 per year to maintain the existing railroad system was deducted from the $177,003,000. Table 22 presents the estimated percent of total grain which would have been shipped to various markets by the single-car system. About 62 percent of the corn and soybeans would have gone to Chicago, almost 25 percent to Iowa processors and less than nine percent would have been shipped to Gulf Export.

Multiple-car rates

Single-car, three- to ten-car and fifty-car rates--The first multiple rail car rates on grain in Iowa were published in 1971. These rates were for 5-, 27-, and 54-car shipments to Houston, Texas. Subsequently, other multiple-car rates were published including three-car export shipments to the Gulf and 25-car and 50-car export shipments to the Gulf, Chicago, and Milwaukee.

An evaluation of the impact of these rates on the optimal grain distribution system was made by using 3-, 10-car and 50-car rates along with single-car rates.

Table 22.

Estimated Percent of Corn and Soybeans Shipped to Selected Markets Under Traditional Single-Car Rail Rates and 1969-70 Prices.

Market	Percent Shipped		
	Corn	Soybeans	Total
Central Iowa	1.86	38.20	16.09
Eastern Iowa	9.80	2.79	7.06
Chicago Export	52.37	48.48	51.15
Chicago Domestic	17.40	0.00	10.59
Central Illinois	0.00	0.00	0.00
Milwaukee Export	0.00	0.00	0.00
Milwaukee Domestic	0.00	0.00	0.00
Kansas	9.32	0.00	5.67
Nebraska	0.37	0.00	0.23
Missouri	0.00	0.00	0.00
Gulf Export	7.88	10.53	8.91
Total	100.00	100.00	100.00

The 50-car rate was assigned to potential subterminal sites. The three-car rate was assigned to elevators located on the railroad offering these rates and the single-car rate was assigned to all other elevators located on a rail line. Elevators without access to a rail line had the option of trucking to a subterminal for transhipment by rail, trucking directly to market or trucking to the Mississippi River for barge shipment to the Gulf. Three alternative rail line options were fed into the computer. These options were rail line option I which would have maintained the line in existence in 1971, rail line option II which would have maintained 46 percent of the rail lines existing in 1971, and rail line option III which would have maintained 27 percent of the 1971 rail lines.

The results of the optimal solutions for the three rail line options are presented in Table 23. The highest net revenue was obtained from a subterminal system of ten subterminals within the 6½ counties loading 50-car trains on rail option III or maintaining 27 percent of the 1971 rail line network. This system would have yielded 5.1 cents net revenue per bushel above the traditional single-car system moving the same quantity of grain.

Table 24 presents the estimated percent of grain which would have been shipped to various markets with the single-car, three- to ten-car, and fifty-car rates under rail line option III. The percent of grain going to Iowa processors would have totaled seven percent; less than one-third would have gone to Chicago, while 61 percent would have gone to Gulf Export. Evidently the multiple-car rates provide a much greater opportunity for Iowa producers to move grain to the Gulf Export markets than would the traditional single-car system.

When rail line option II, maintaining 46 percent of the 1971 rail line system was substituted for option III (27 percent), net revenue would have declined $182,000 per year or 0.2 cents per bushel. The increase in revenue over the traditional single-car system was 4.9 cents per bushel. The optimum number of subterminals would have been 13 in this solution because there were more miles of rail line than in rail option III.

When rail line option I, maintaining all 1971 rail lines at their existing carrying capacity, was substituted for rail option III, total joint net revenue would have declined $1,601,000 per year or 1.4 cents per bushel. However, this system still would have yielded 3.7 cents per bushel over the traditional single-car system.

Table 23.

Results of the Optimal Solutions for Grain Distribution Systems based on Single-Car, Three- to Ten-Car and Fifty-Car Rail Rates on Three Rail Line Options and 1969-70 Grain Prices.

Item	Rail Line Options: Option I Maintain 1971 Rail System	Option II Keep 46 Percent of 1971 Rail System	Option III Keep 27 Percent of 1971 Rail System
Total revenue minus all transportation, storage and variable handling costs	$182,178,000	$182,846,000	$181,990,000
Less annual subterminal investment costs	$764,000	$1,000,000	$775,000
Less annual rail line maintenance and upgrading costs	$2,794,000	$1,807,000	$994,000
Total joint net revenue	$178,620,000	$180,039,000	$180,221,000
Number of subterminals in 6½-county area	10	13	10
Increase in total joint net revenue over 1971 system	$4,411,000	$5,830,000	$6,012,000
Increase in net revenue over 1971 system from:			
a. rail rate reductions less trucking and handling costs	$4,411,000	$4,843,000	$4,212,000
b. reduction in rail line maintenance costs	0	$987,000	$1,800,000
Increase in total joint net revenue over 1971 system in cents per bushel	3.7	4.9	5.1
Increase in net revenue in cents per bushel over 1971 system from:			
a. rail rate reductions less trucking and handling costs	3.7	4.1	3.6
b. reductions in rail line maintenance costs	0.0	0.8	1.5

Table 24.

Estimated Percent of Corn and Soybeans Shipped to Selected Markets Under Single-Car, Three- to Ten-Car and Fifty-Car Rail Rates, Rail Line Option III (27 percent) and 1969-70 Grain Prices.

	Percent Shipped		
Market	Corn	Soybeans	Total
Central Iowa	0.00	3.57	1.31
Eastern Iowa	8.69	0.37	5.64
Chicago Export	33.80	24.97	30.57
Chicago Domestic	0.89	0.00	0.56
Central Illinois	0.00	0.00	0.00
Milwaukee Export	0.00	0.00	0.00
Milwaukee Domestic	0.00	0.00	0.00
Kansas	1.44	0.00	0.91
Nebraska	0.00	0.00	0.00
Missouri	0.00	0.00	0.00
Gulf Export	55.18	71.09	61.01
Total	100.00	100.00	100.00

Under rail line option III, 3.6 cents per bushel or 71 percent of the increased income would have been derived from rail rate reductions while 1.5 cents per bushel or 29 percent would have come from reduced rail line maintenance. Under rail line option II, 4.1 cents per bushel or 85 percent of the increased income would have been obtained from rail rate reductions and 0.8 cents per bushel or 15 percent from reduced rail line costs. Under rail line option I, 100 percent of the increased net income would have come from reduced rail rates less additional maintenance costs. Presumably, the increased net revenue from greater utilization of multiple-car rates would be passed on to the shipper.

At the present time, subterminals operating in the area are experiencing price discounts of up to 15 cents per bushel for 50-car shipments when privately owned or leased cars are provided by the buyer. This practice represents efforts by the buyers to capitalize the value of the cars into the price of the grain. Assuming an adequate supply of railroad or privately furnished equipment, competitive pressures would probably preclude the discounting practices.

Figures 8, 9, and 10 show the probable flow of corn from elevators direct to market and to subterminals for the three rail line options. Lines from a country elevator to subterminals indicate that corn would be trucked from that elevator to the subterminal for transhipment to market in a 50-car train.

The differences among the flows are primarily a result of the differences in rail line options. The optimal number of subterminals was 10 for rail line option I, 13 for rail line option II and 10 for rail line option III. Rail line option I had fewer subterminals than option II because all the existing rail lines were maintained in option I and a larger number of elevators would have shipped direct to market. There were three less subterminals in rail line option III than option II because only 27 percent of the rail lines remained in existence.

Table 25 identifies the subterminals which were selected as optimal locations for the three rail line options along with the number of bushels of grain shipped through each location. The number of bushels handled by subterminals located within the 6½-county area for the three rail line options would have ranged from a low of 4.0 million bushels to a high of 15.7 million bushels. Subterminals located outside of but adjacent to the area would have received from 0.7 to 5.2 million bushels from within the area. The average number of bushels shipped per

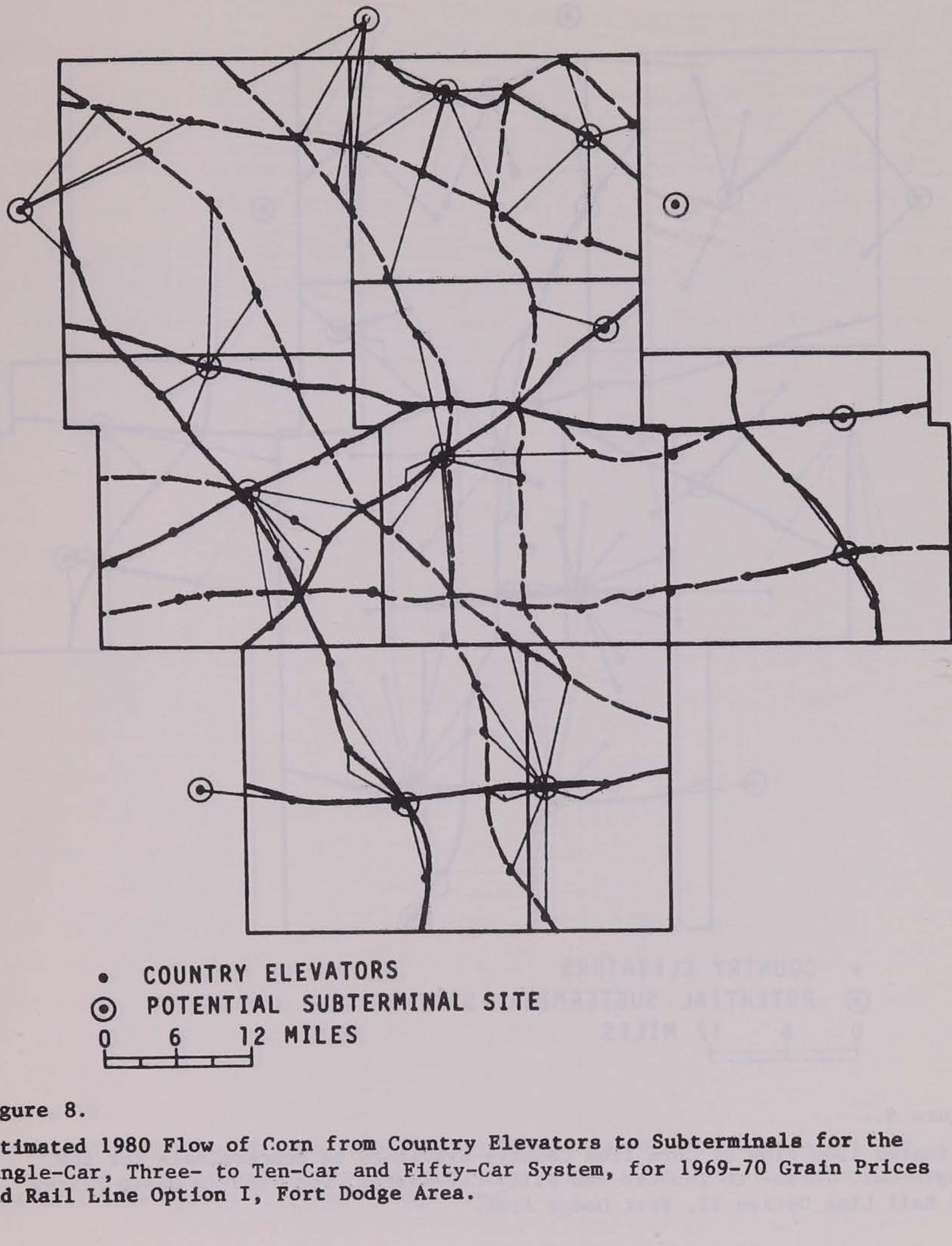


Figure 8.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option I, Fort Dodge Area.

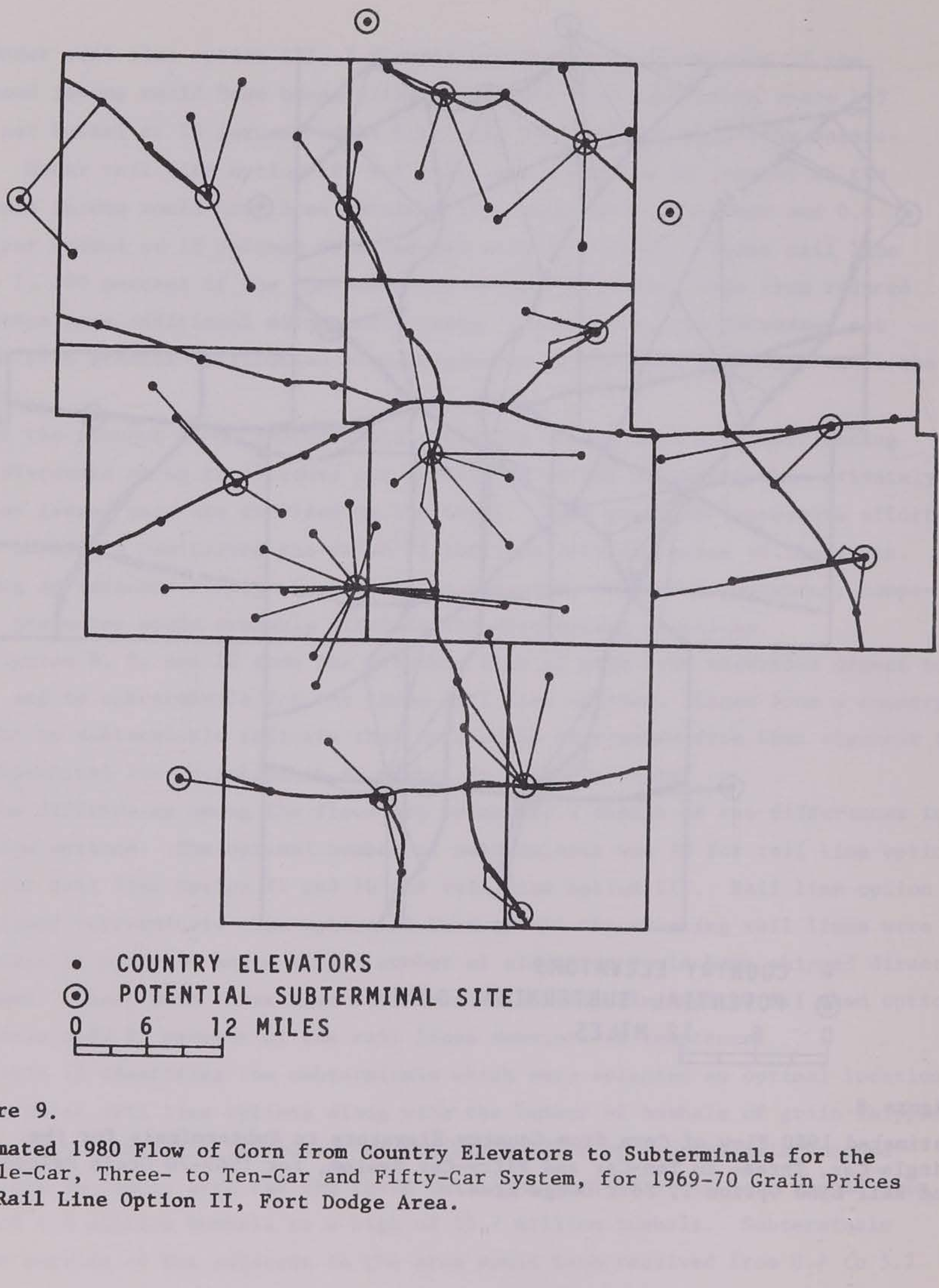


Figure 9.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices **and Rail Line Option II, Fort Dodge Area.**

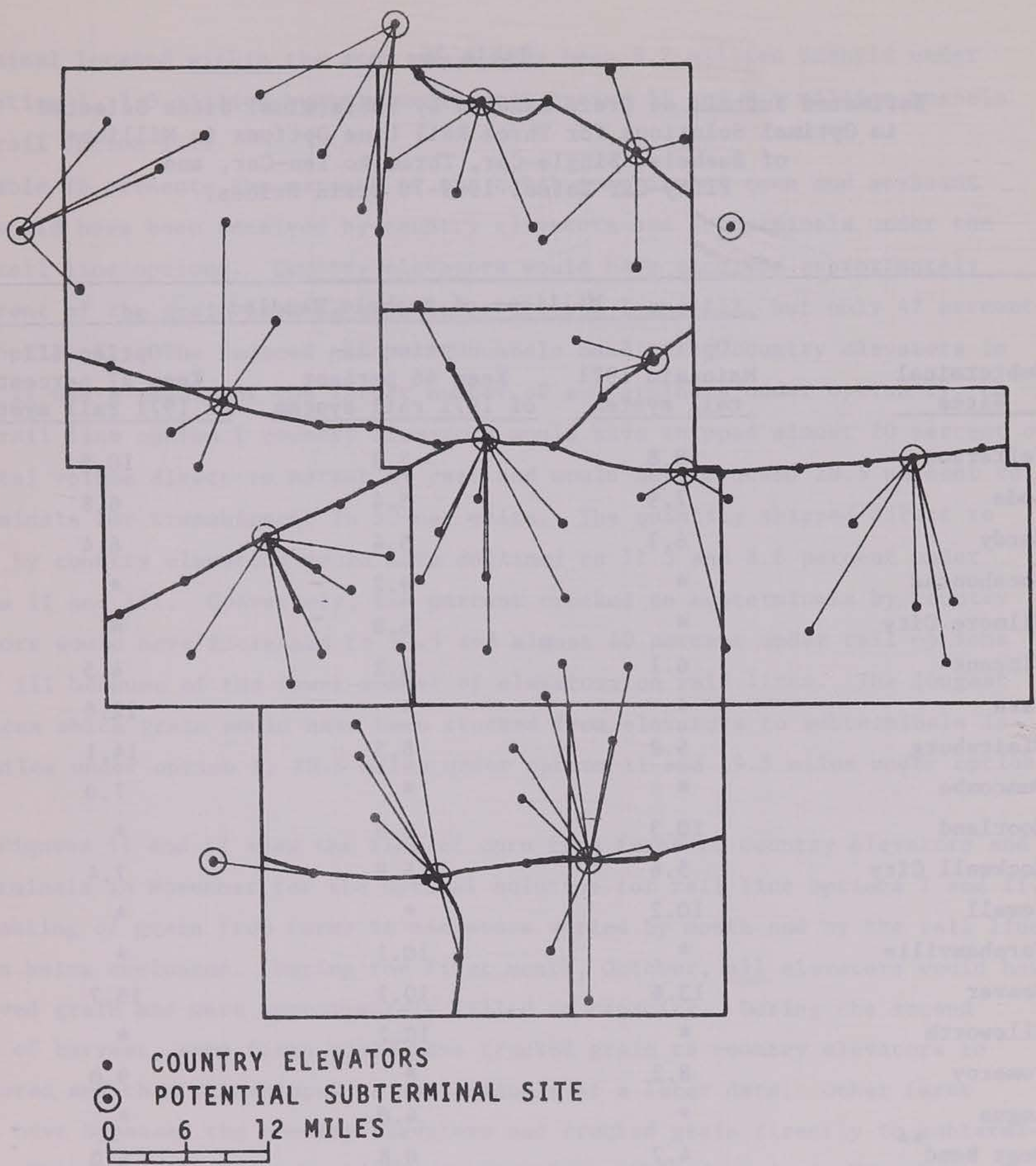


Figure 10.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices **and Rail Line Option III, Fort Dodge Area.**

Table 25.

Estimated Bushels of Grain Handled by Subterminal Sites Selected in Optimal Solutions for Three Rail Line Options in Millions of Bushels, Single-Car, Three to Ten-Car, and Fifty-Car Rates, 1969-70 Grain Prices.

Subterminal Sites	Millions of Bushels Handled		
	Option I Maintain 1971 rail system	Option II Keep 46 percent of 1971 rail system	Option III Keep 27 percent of 1971 rail system
Jefferson	8.8	7.3	10.5
Bode	7.9	5.4	6.8
Hardy	6.3	6.4	6.4
Pocahontas	*	9.2	*
Gilmore City	*	6.8	*
Vincent	6.1	6.2	4.5
Tara	*	*	12.6
Blairsburg	5.2	6.5	14.1
Duncombe	*	*	7.0
Moorland	10.3	8.5	*
Rockwell City	5.6	5.9	7.4
Jewell	10.2	*	*
Farnhamville	*	10.1	*
Beaver	13.6	10.7	15.7
Ellsworth	*	10.7	*
Pomeroy	8.2	*	9.0
Angus	*	4.0	*
West Bend**	4.7	0.8	5.0
Albert City**	4.8	2.7	5.2
Ralston**	2.9	2.8	2.9
Goldfield**	0.7	0.7	0.7

* Not selected under this rail line option.
** Located outside of the 6½-county area.

subterminal located <u>within</u> the area would have been 8.2 million bushels under rail option I, 7.5 million bushels under rail option II and 9.4 million bushels under rail option III.

Table 26 presents the percent of the total quantity of corn and soybeans which would have been received by country elevators and subterminals under the three rail line options. Country elevators would have received approximately 48 percent of the grain from farmers under options I and III, but only 42 percent under option II. The reduced number of bushels handled by country elevators in option II was a result of the larger number of subterminals under option II. Under rail line option I country elevators would have shipped almost 20 percent of the total volume direct to market by rail and would have trucked 28.5 percent to subterminals for transhipment in 50-car units. The quantity shipped direct to market by country elevators would have declined to 11.5 and 8.6 percent under options II and III. Conversely, the percent trucked to subterminals by country elevators would have increased to 30.5 and almost 40 percent under rail options II and III because of the fewer number of elevators on rail lines. The longest distances which grain would have been trucked from elevators to subterminals is 20.5 miles under option I, 20.5 miles under option II and 19.5 miles under option III.

Figures 11 and 12 show the flow of corn from farms to country elevators and subterminals in November for the optimal solution for rail line options I and II. The routing of grain from farms to elevators varied by month and by the rail line option being evaluated. During the first month, October, <u>all</u> elevators would have received grain and were approximately filled to capacity. During the second month of harvest, some farms would have trucked grain to country elevators to be stored and then transhipped to subterminals at a later date. Other farms would have bypassed the country elevators and trucked grain directly to subterminals. However, all elevators with one exception received grain in November. The one exception was a small 35,000-bushel capacity elevator.

This strongly suggests that the subterminal system will not force an existing country elevator out of business even if the elevator has no rail line. This conclusion is supported by Appendix H which presents a budget prepared for an actual country elevator located in the 6½-county area. This budget assumes that the elevator will lose its railroad line. The conclusion from the budget is that

Table 26.

Percent of Total Bushels of Corn and Soybeans Received by Country Elevators and Subterminals by Rail Line Options, 1969-70 Grain Prices.

	Option I Maintain 1971 rail system	Option II Keep 46 percent of 1971 rail system	Option III Keep 27 percent of 1971 rail system
Received by country elevators from farmers and shipped direct to market by rail	19.1	11.5	8.6
Received by country elevators from farmers and trucked to subterminals for transhipment by rail	28.5	30.5	39.3
Received by subterminals and shipped by 50 car units	52.4	58.0	52.1

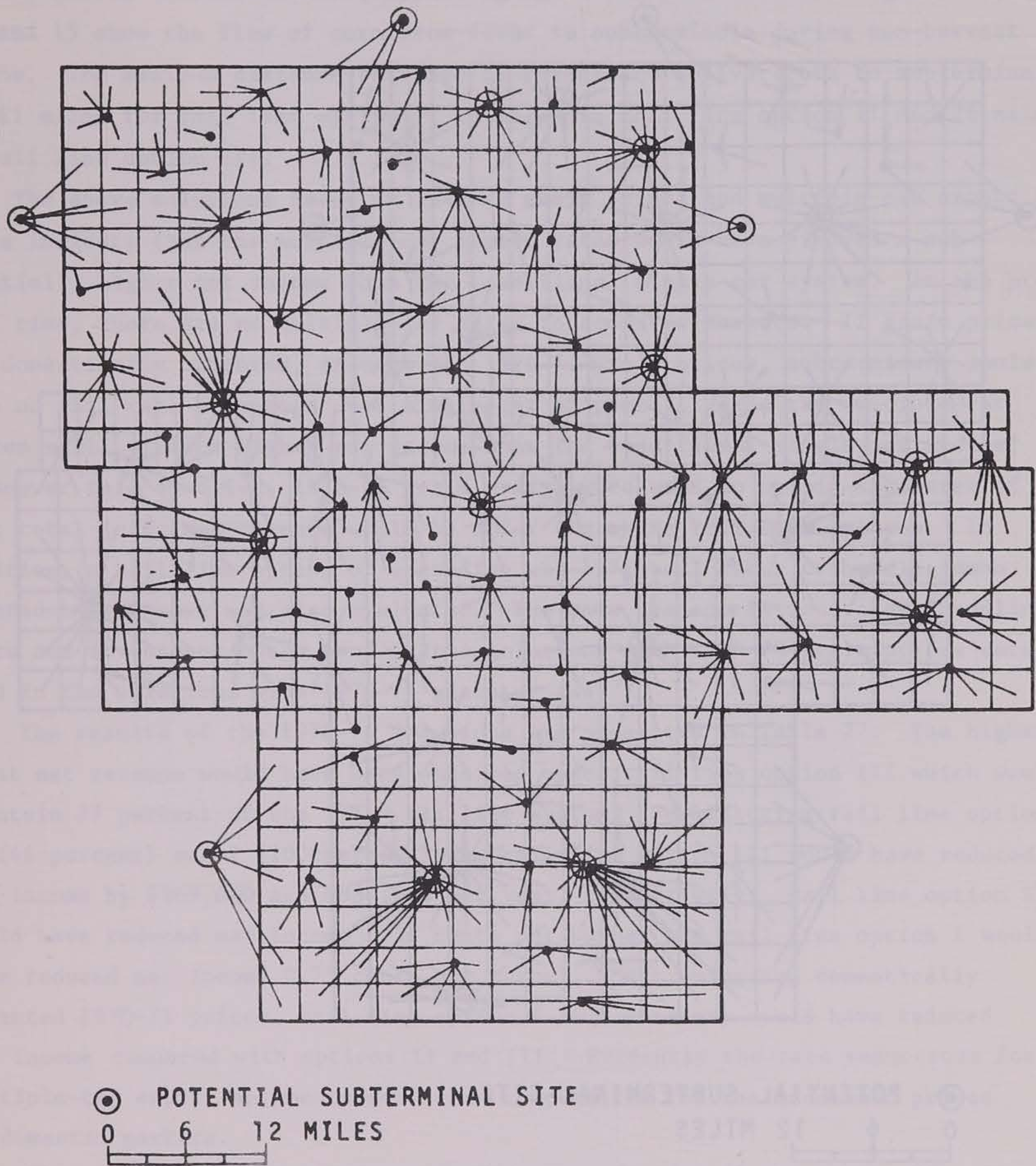


Figure 11.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option I, During Harvest, Fort Dodge Area.

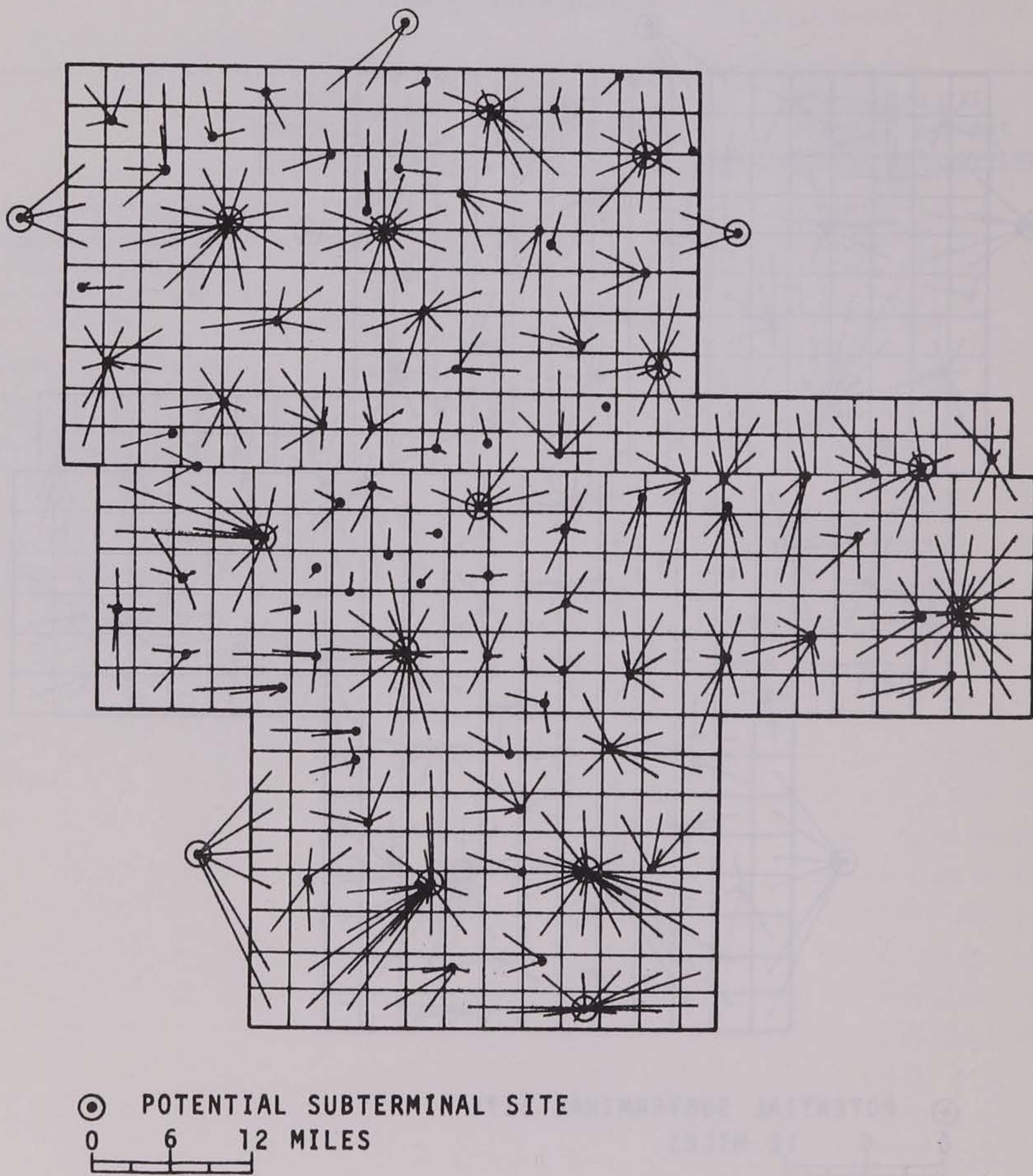


Figure 12.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option II, During Harvest, Fort Dodge Area.

elevators losing their railroad line would be better off to remain in business than to liquidate.

In December and in all other non-harvest months, farmers would have trucked grain directly to subterminals, bypassing all country elevators. Figures 13, 14, and 15 show the flow of corn from farms to subterminals during non-harvest months. The maximum distance traveled by farmers to deliver corn to subterminals was 21 miles for rail line option I, 24 miles in rail line option II and 26 miles in rail line option III.

The above solutions based on 1969-70 grain prices and multiple-car export rates indicate that the multiple-car export rates would have yielded a substantially higher net income than the traditional single-car system. At the present time, there are no multiple-car rates to domestic markets. If grain prices are domestically oriented, as were the 1970-71 grain prices, subterminals would have no rail rate advantage over single-car shippers. Would the multiple-car system still yield a higher net income than the traditional single-car system? To answer this question, 1970-71 grain prices were used to obtain estimates of what total joint net revenue would be under the three rail line options. In addition, a rail line option of upgrading all 1971 rail lines to handle jumbo covered hopper cars was also evaluated. The same transportation rates, handling costs and investment costs used in the solutions with 1969-70 grain prices were used in the solutions with 1970-71 grain prices.

The results of the 1970-71 solutions are presented in Table 27. The highest joint net revenue would have been obtained under rail line option III which would maintain 27 percent of the 1971 rail line system. Substituting rail line options II (46 percent) and I (100 percent) for rail line option III would have reduced net income by $369,000 and $884,000 per year, respectively. Rail line option II would have reduced net income 0.31 cents per bushel and rail line option I would have reduced net income 0.75 cents per bushel. Even using the domestically oriented 1970-71 prices, rail line option I (100 percent) would have reduced net income compared with options II and III. Evidently the rate reductions for multiple-car export shipments more than compensates for the increased prices at domestic markets.

There would have been a very significant reduction in net income if rail

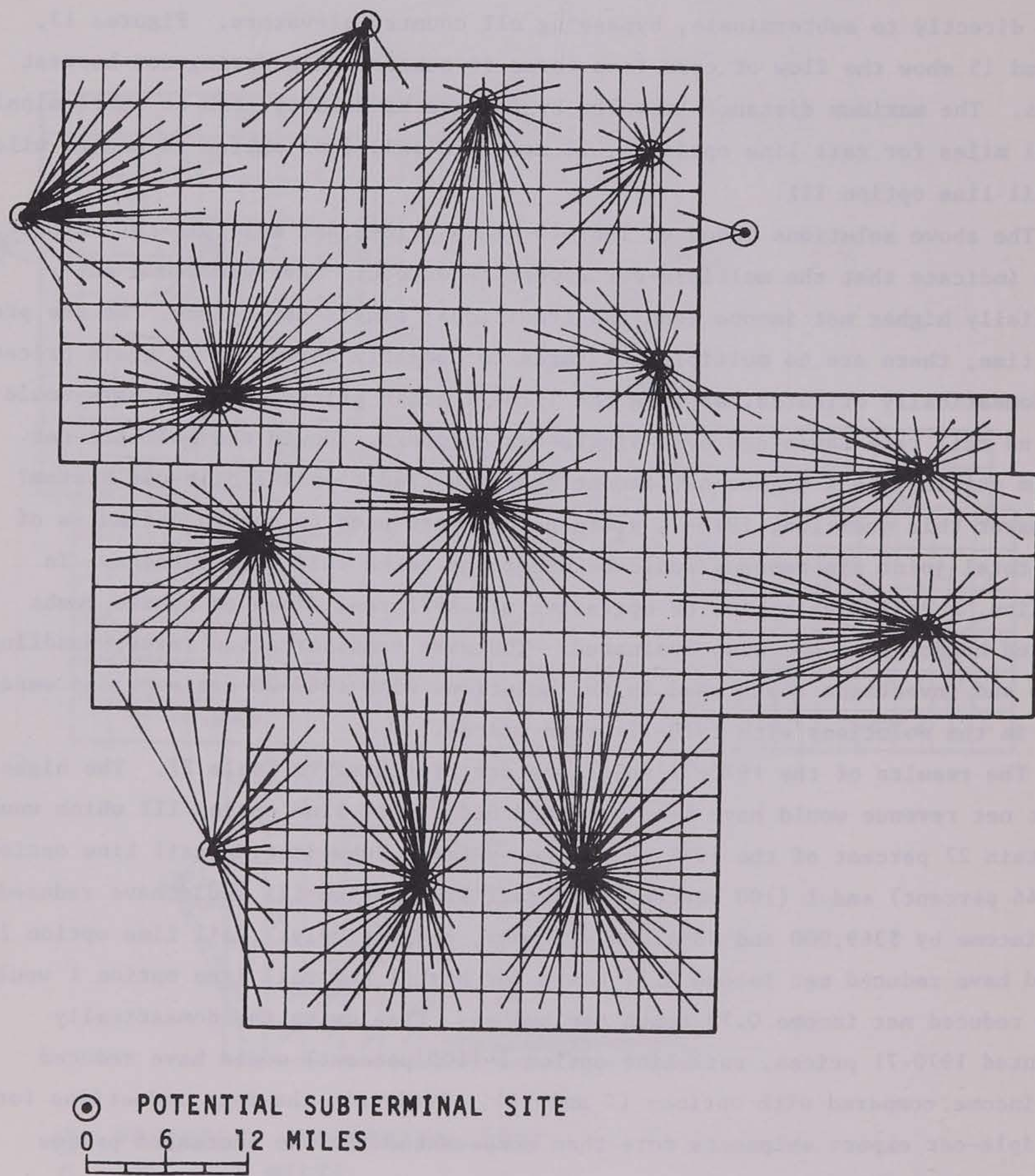


Figure 13.

Estimated Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option I, During Non-Harvest Months, Fort Dodge Area.

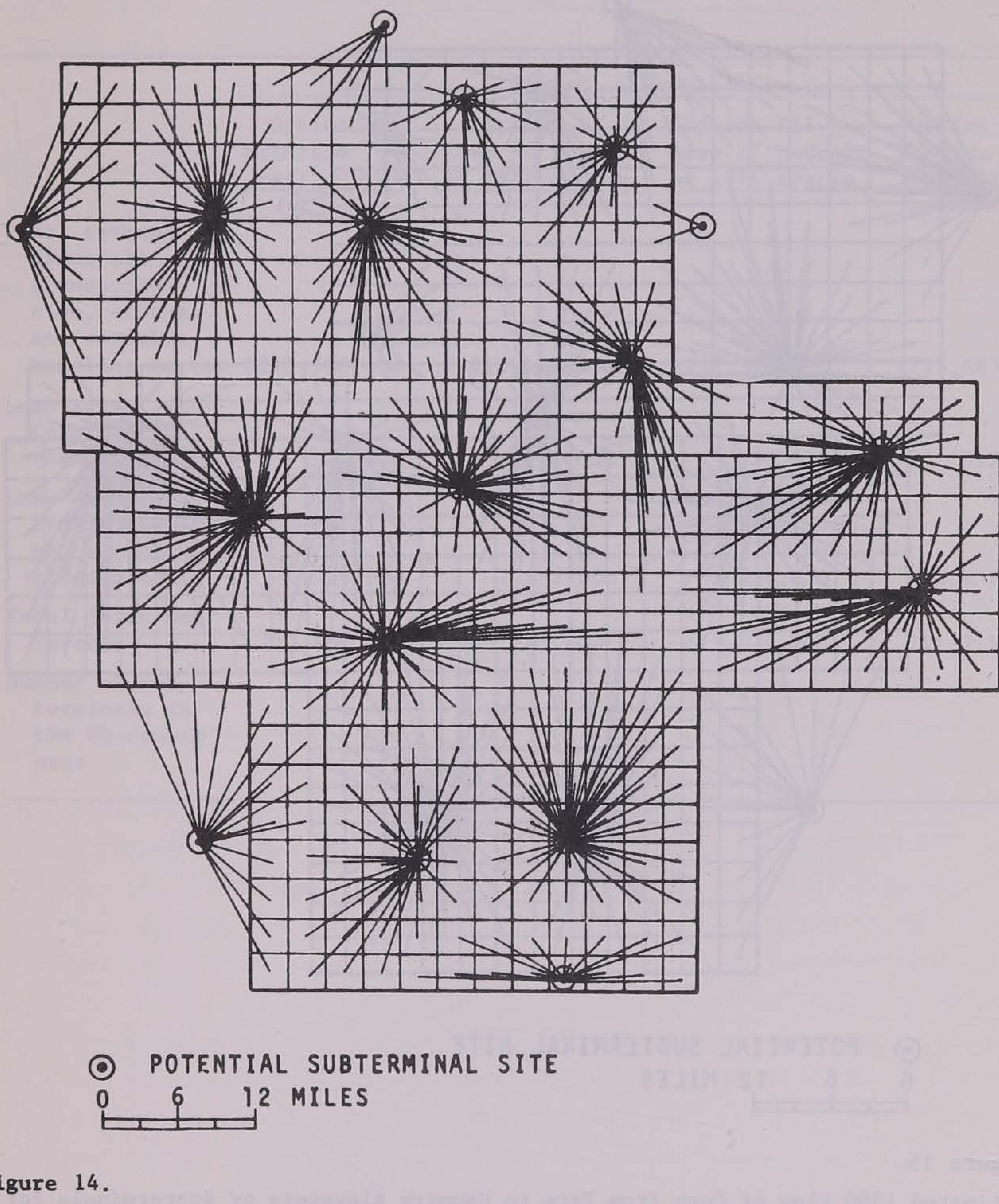


Figure 14.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option II, During Non-Harvest Months, Fort Dodge Area.

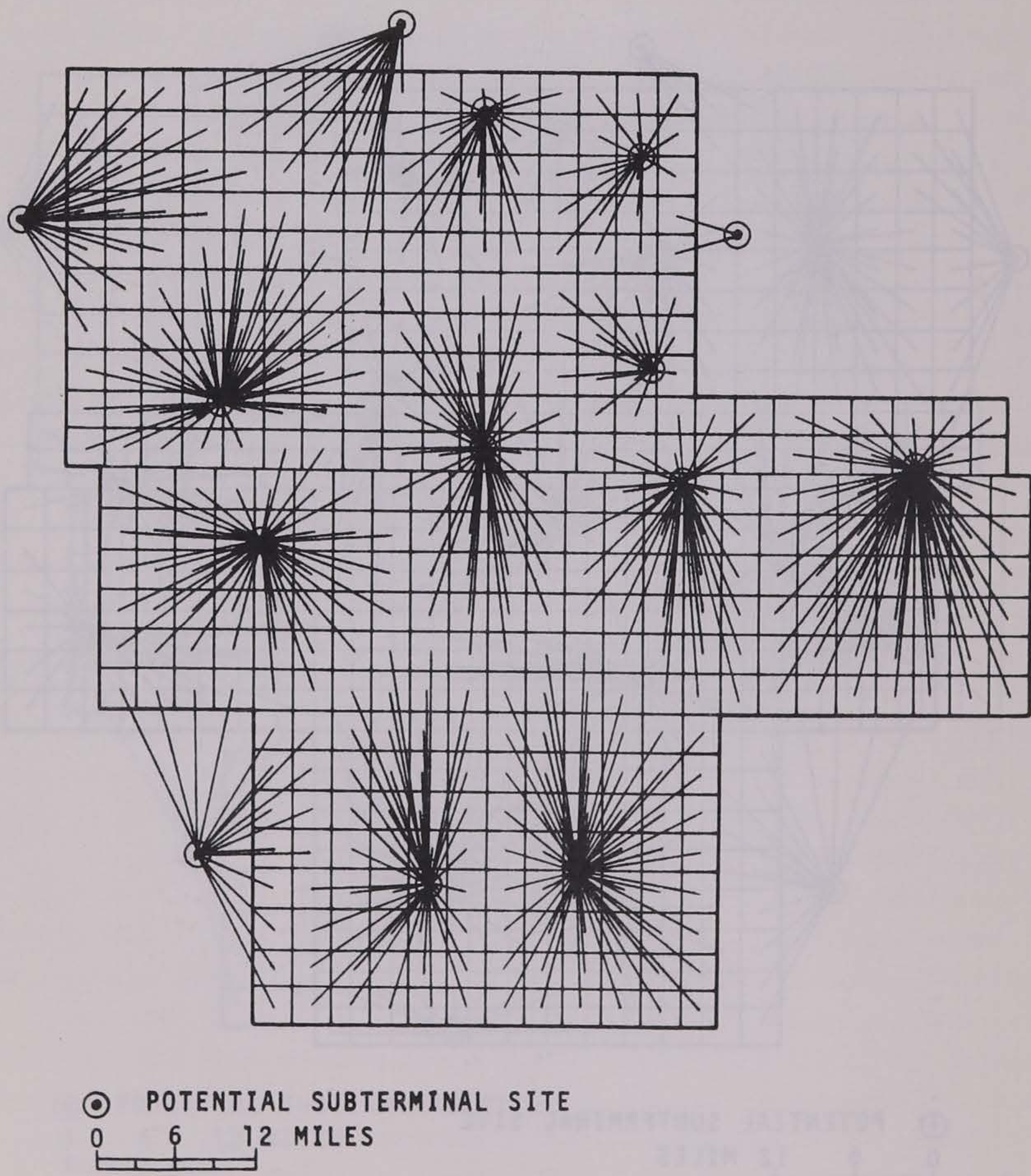


Figure 15.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1969-70 Grain Prices and Rail Line Option III, During Non-Harvest Months, Fort Dodge Area.

Table 27.

Results of the Optimal Solutions for Grain Distribution Systems on Single-Car, Three to Ten-Car and Fifty-Rail Car Rates on Four Rail Line Options and 1970-71 Grain Prices.

	Rail Line Options			
	Option I Maintain 1971 rail system	Option II Keep 46 percent of 1971 system	Option III Keep 27 percent of 1971 system	Option IV Upgrade all light lines
Total revenue minus all transportation, storage and variable handling costs	$215,520,000	$215,104,000	$214,598,000	$215,663,000
Less annual sub-terminal investment costs	536,000	592,000	530,000	592,000
Less annual rail line maintenance and upgrading costs	2,794,000	1,807,000	994,000	3,857,000
Total joint net revenue	212,190,000	212,705,000	213,074,000	211,214,000
Number of sub-terminals in the 6½-county area	7	8	7	8

line option IV, upgrading all 1971 rail lines to handle jumbo hopper cars at 35 miles per hour, had been substituted for rail line option III, (27 percent). Net income in this case would have declined $1,860,000 per year or 1.6 cents per bushel. The annual cost of upgrading all lines was almost 50 percent more than the annual cost of maintaining the present lines; it was more than double the cost of option II and almost 4 times as large as the annual cost of maintaining 27 percent of the 1971 rail system.

Table 28 presents the estimated percent of grain shipped to various markets under single-car, three- to ten-car and 50-car rates using 1970-71 grain prices and rail line option II. Iowa processors would have received almost seven percent of the grain, about the same as under 1969-70 prices. Chicago export would have received 27 percent, compared to 31 percent under 1969-70 prices. Chicago processors would have received 22 percent, compared to less than one percent under 1969-70 prices. Nebraska would have received 1.5 percent, compared to zero under 1969-70 prices. Gulf Export would have received 42 percent, compared to 61 percent under 1969-70 prices and less than nine percent under the traditional single-car system using 1969-70 prices. Thus, the subterminal system with existing multiple-car export rates would substantially increase grain export potential from Iowa, even under 1970-71 prices which were domestically oriented.

At the present time there are no multiple-car rates for shipments to domestic markets originating in Iowa. If these rates were available, the percent of grain going to the domestic markets under both sets of prices would have increased substantially.

There would have been fewer subterminals in the 1970-71 price solutions than in the 1969-70 solutions. This is a result of the higher domestic prices in 1970-71 and only single-car rates to domestic markets. Figures 16, 17, and 18 show the flow of grain from elevators to subterminals, and the flow of grain from farms to elevator during harvest and non-harvest months under the 1970-71 prices and rail line option II.

<u>Single-car, three- to ten-car and one hundred and fifteen-car rates</u>--A fourth set of solutions was generated by substituting the estimated 115-car rates for the 50-car rates, using 1969-70 grain prices. The 115-car rate is based on a guaranteed annual volume of 517,500 tons per year and is available

Table 28

Estimated Percent of Corn and Soybeans Shipped to Selected Markets Under Single-Car, Three- to Ten-Car and Fifty-Car Rail Rates, Rail Line Option II (46 percent) and 1970-71 Grain Prices.

Market	Percent Shipped Corn	Percent Shipped Soybeans	Percent Shipped Total
Central Iowa	0.00	13.54	4.96
Eastern Iowa	2.24	0.33	1.54
Chicago Export	18.67	41.24	26.94
Chicago Domestic	34.66	0.00	21.96
Central Illinois	0.00	0.00	0.00
Milwaukee Export	0.00	0.00	0.00
Milwaukee Domestic	0.00	0.00	0.00
Kansas	1.49	0.00	0.95
Nebraska	2.24	0.00	1.42
Missouri	0.00	0.00	0.00
Gulf Export	40.70	44.89	42.23
Total	100.00	100.00	100.00

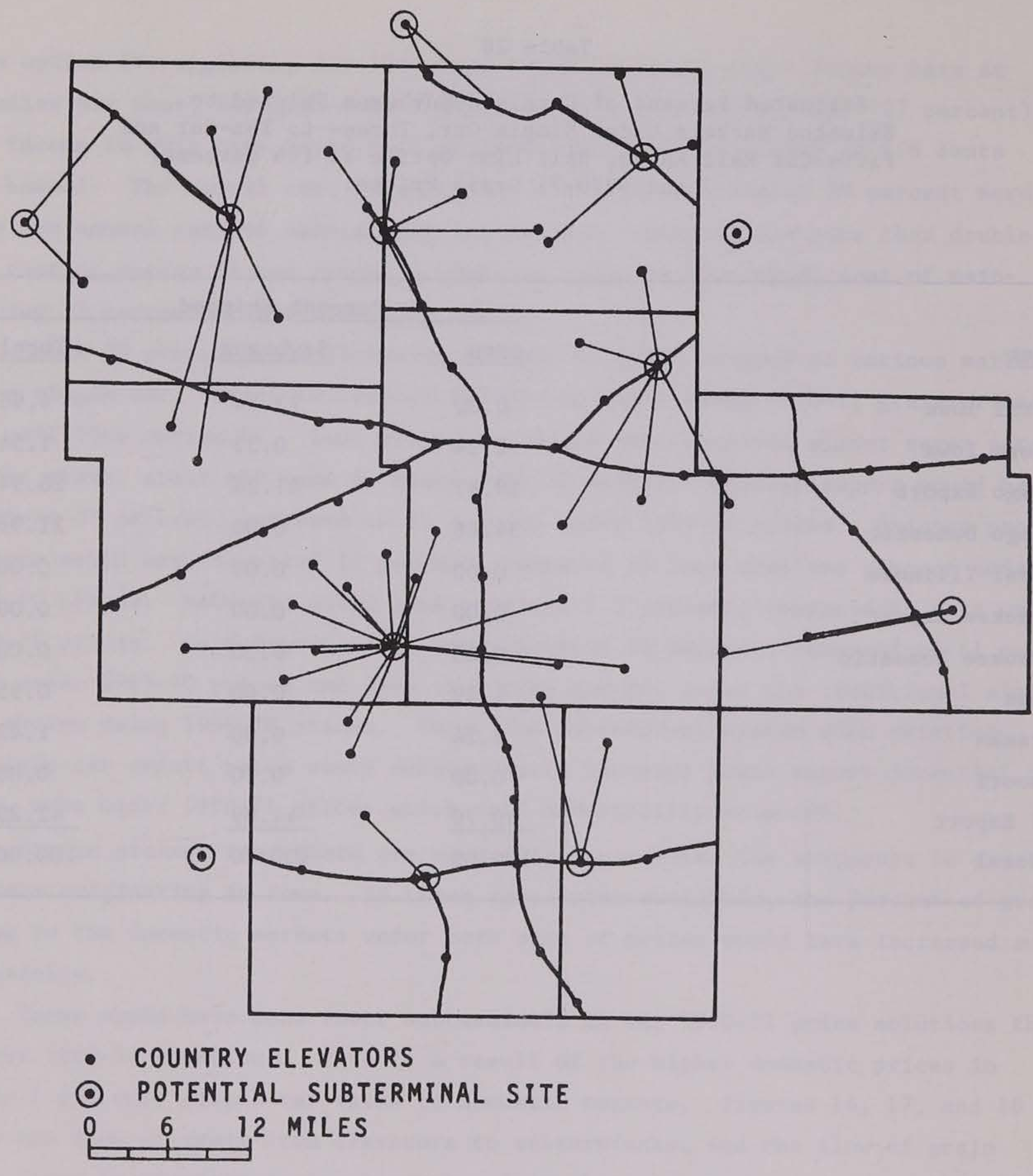


Figure 16.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1970-71 Grain Prices and Rail Line Option II, Fort Dodge Area.

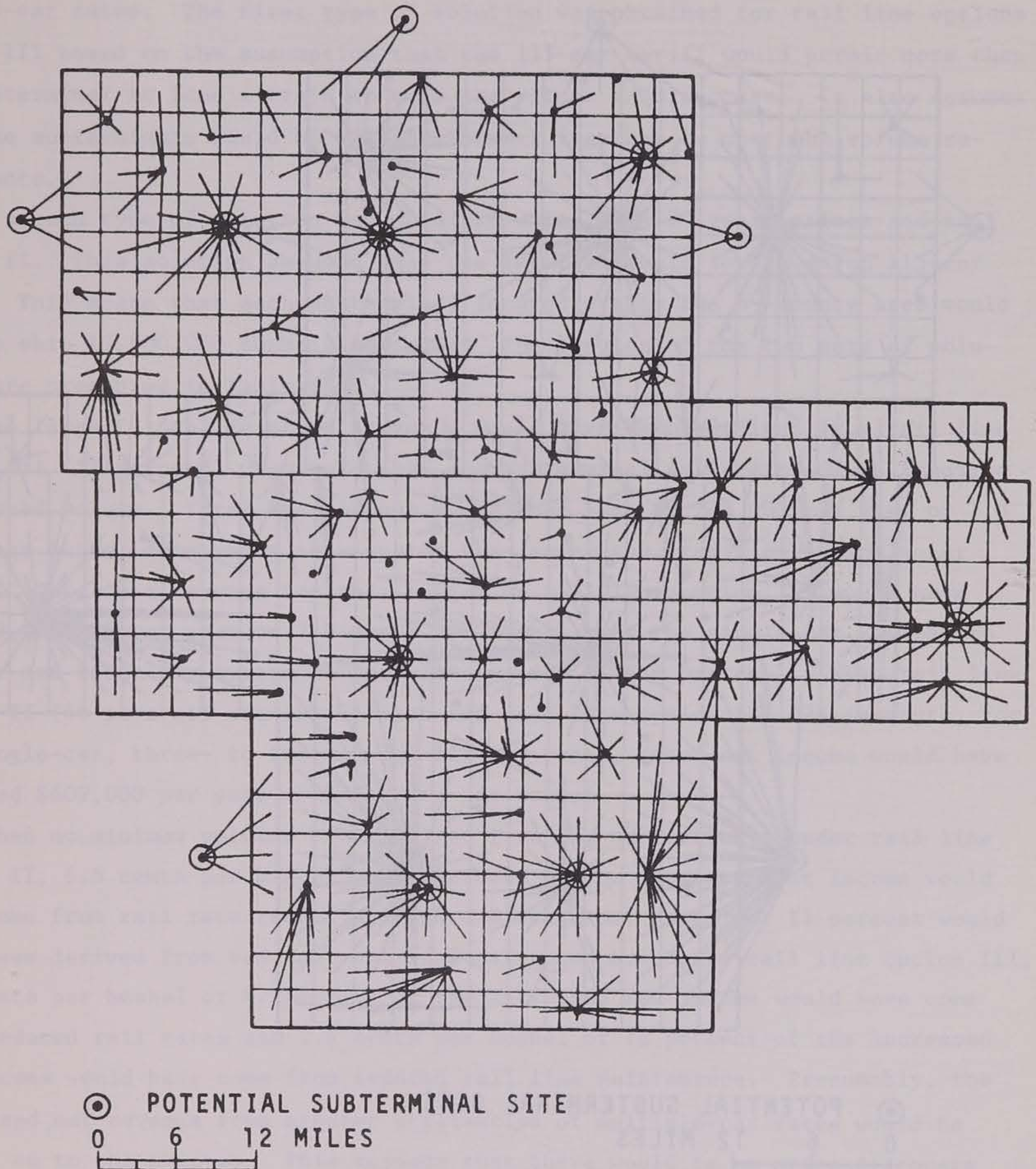


Figure 17.

Estimated 1980 Flow of Corn from Farm to Country Elevators and Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1970-71 Grain Prices and Rail Line Option II, During Harvest, Fort Dodge Area.

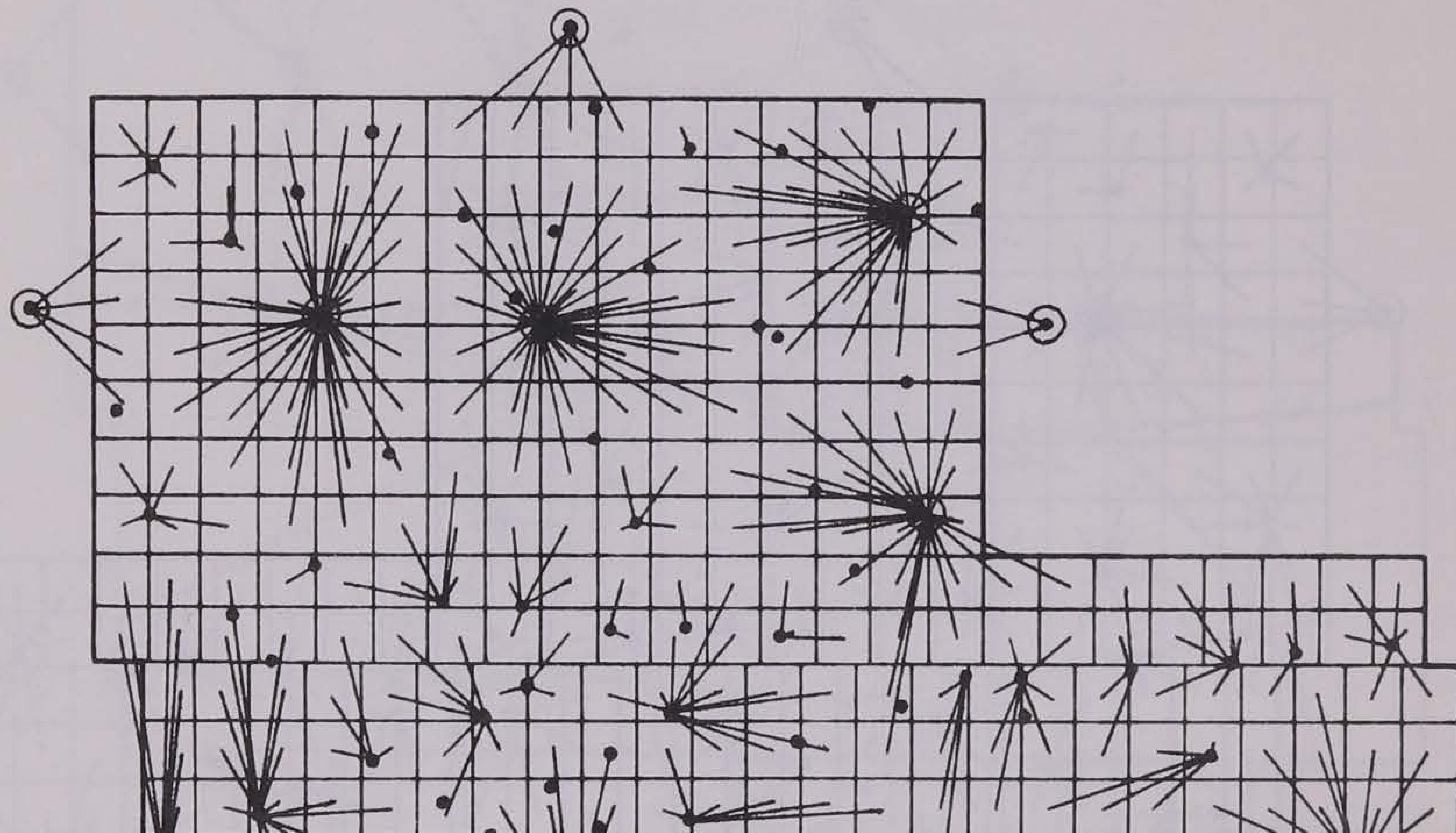


Figure 18.

Estimated 1980 Flow of Corn from Farm to Country Elevators and Subterminals for the Single-Car, Three- to Ten-Car and Fifty-Car System, for 1970-71 Grain Prices and Rail Line Option II, During Non-Harvest Months, Fort Dodge Area.

in East Central Illinois. This guaranteed volume from Iowa would require the train to run continuously throughout the year. A rate based on this tariff was estimated for the Fort Dodge area. Two types of solutions were obtained using the 115-car rates. The first type of solution was obtained for rail line options II and III based on the assumption that the 115-car tariff would permit more than one subterminal to load a train to meet the volume requirements. It also assumes that the subterminals would be willing to work together to meet the volume requirements.

A second type of solution was obtained using 1969-70 grain prices and rail option II. This solution assumed only one location could load a given 115-car train. This means that each subterminal located within the 6½-county area would need to ship 17,500,000 bushels per year. The results of the two sets of solutions are presented in Table 29.

The largest total joint net revenue would have been obtained from rail line option III (27 percent) when more than one subterminal is permitted the required guaranteed volume. Total net revenue would have been $9,245,000 per year or 7.8 cents per bushel more under this system than under the traditional single-car system. Total net revenue for this system on rail line option III would have been $3,415,000 per year or 2.9 cents per bushel over the single-car, three- to ten-car and fifty-car system on rail line option II (46 percent). When rail line option II (46 percent) was substituted for rail line option III (27 percent), for the single-car, three- to ten-car and 115-car rates, total net income would have declined $609,000 per year or 0.5 cents per bushel.

When no minimum volumes are required from the subterminals under rail line option II, 6.5 cents per bushel or 89 percent of the increased net income would have come from rail rate reductions and 0.8 cents per bushel or 11 percent would have been derived from reduced rail line maintenance. Under rail line option III, 6.4 cents per bushel or 82 percent of the increased net income would have come from reduced rail rates and 1.4 cents per bushel or 18 percent of the increased net income would have come from reduced rail line maintenance. Presumably, the increased net revenue from greater utilization of multiple-car rates would be passed on to the shipper. This assumes that there would be no price discounts for grain shipped by the continuous trains.

Figures 19, 20, and 21 present the flow of grain from elevators to subterminals

Table 29.

Results of the Optimal Solutions for Grain Distribution Systems Based on Single-Car, Three- to Ten-Car, and One-Hundred Fifteen-Car Rail Rates on Two Rail Line Options, 1969-70 Grain Prices and Minimum and No Minimum Subterminal Volumes.

	No Minimum Subterminal Volumes		17,500,000-Bushel Minimum Volume
Item	Option II Keep 46 Percent of 1971 Rail System	Option III Keep 27 percent of 1971 Rail System	Option II Keep 46 Percent of 1971 Rail System
Total revenue minus all transportation, storage and variable handling costs	$185,991,000	$185,356,000	$185,196,000
Less annual subterminal investment costs	$1,339,000	$908,000	$743,000
Less annual rail line maintenance and upgrading costs	$1,807,000	$994,000	$1,807,000
Total joint net revenue	$182,845,000	$183,454,000	$182,646,000
Number of subterminals in the 6½-county area	9	6	5
Increase in total joint net revenue over 1971 system in dollars	$8,636,000	$9,245,000	$8,437,000
Increase in total net revenue over the 1971 traditional system from:			
a. rail rate reductions less trucking and handling costs.	$7,649,000	$7,445,000	$7,450,000
b. reduction in rail line maintenance costs	$987,000	$1,800,000	$987,000
Increase in total joint net revenue over 1971 system in cents per bushel	7.3	7.8	7.1
Increase in net revenue over 1971 system in cents per bushel from:			
a. rail rate reductions less trucking and handling costs	6.5	6.4	6.3
b. reductions in rail line maintenance costs	0.8	1.4	0.8

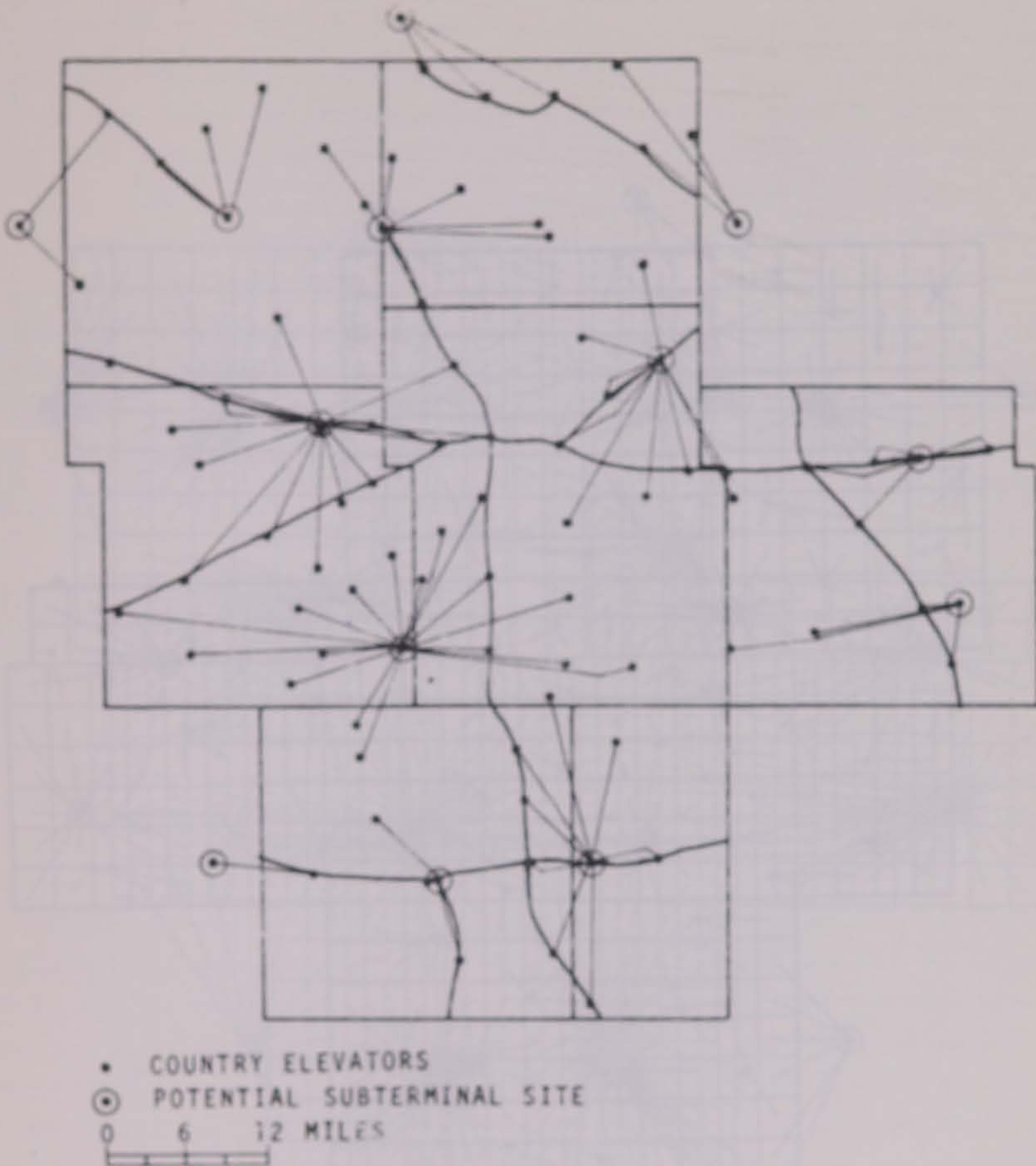


Figure 19.

Estimated Flow of Corn from Country Elevators to Subterminals for the Single-Car, Three- to Ten-Car and 115-Car System, for 1969-70 Grain Prices and Rail Line Option II, Fort Dodge Area.

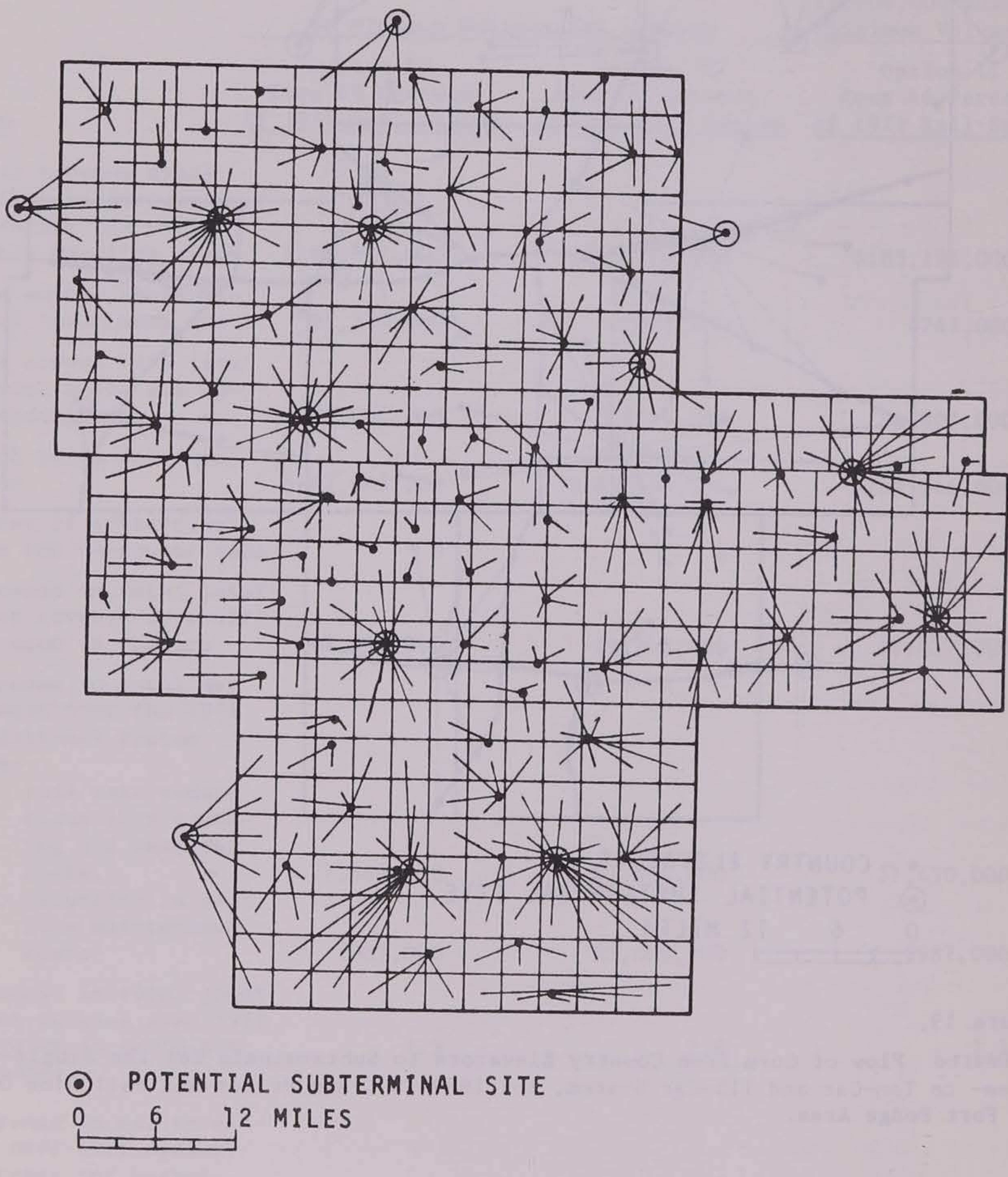


Figure 20.

Estimated Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and 115-Car System, for 1969-70 Grain Prices and Rail Line Option II, During Harvest, Fort Dodge Area.

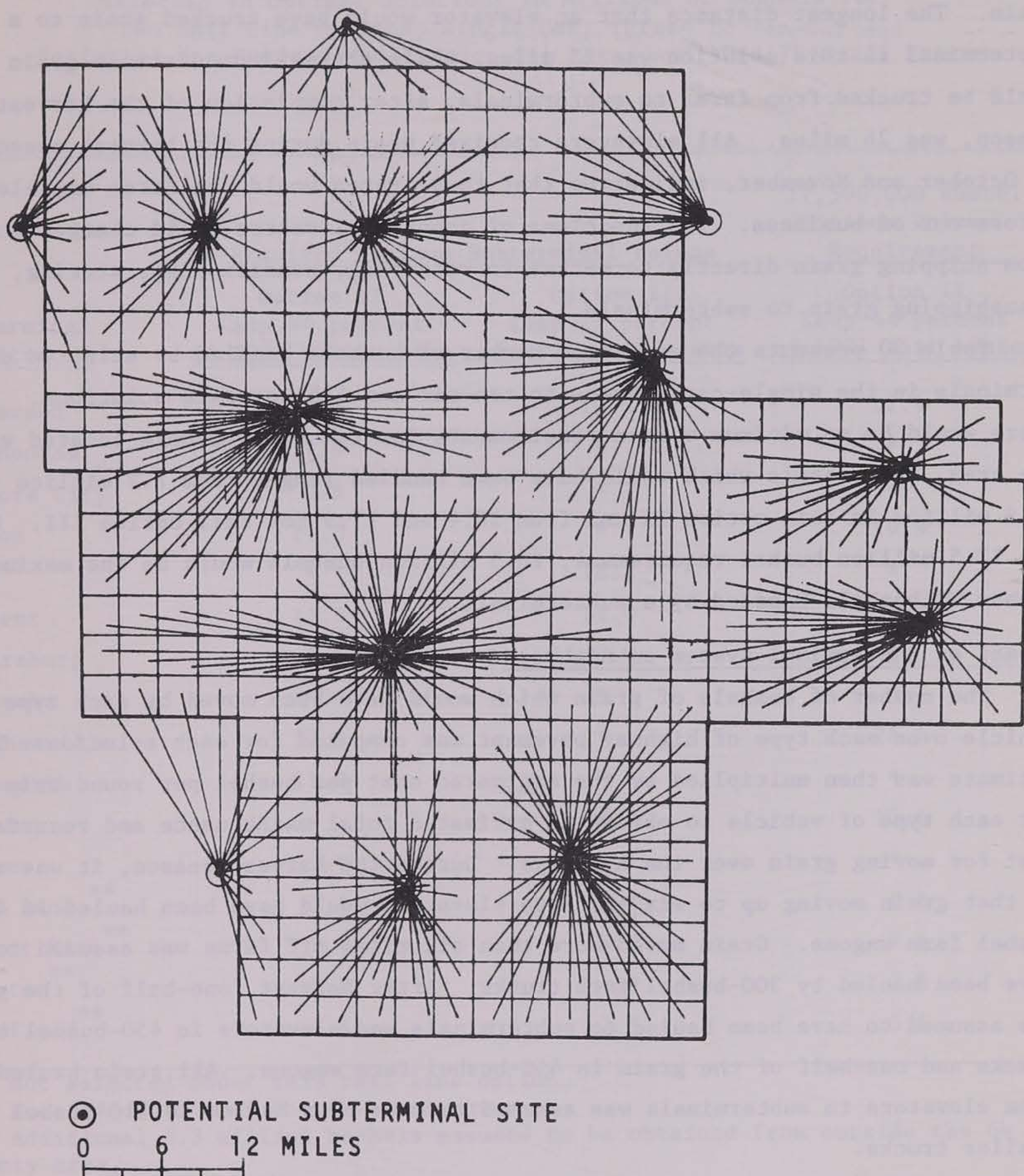


Figure 21.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Single-Car, Three- to Ten-Car and 115-Car System, for 1969-70 Grain Prices and Rail Line Option II, During Non-Harvest Months, Fort Dodge Area.

and farms to elevators and subterminals for rail option II when there is no minimum amount of grain required from each subterminal. All country elevators would have trucked all their grain to subterminals for transhipment in the 115-car train. The longest distance that an elevator would have trucked grain to a subterminal in this solution was 25 miles, while the maximum distance grain would be trucked from farms to subterminals, after completion of the harvest season, was 26 miles. All elevators received grain during the harvest season of October and November, indicating that these rates would not force any elevators out of business. The functions of country elevators would change, however, from shipping grain directly to market to receiving, conditioning, storing, and transhipping grain to subterminals.

Table 30 presents the estimated number of bushels handled by selected subterminals in the single-car, three- to ten-car and 115-car rate solutions. If there would be no minimum volume requirements for the subterminals located within the area, the bushels which would have been handled ranged from 7.2 million to 17.9 million in rail option II and from 10.4 and 17.9 for rail option III. Under the 17.5 million bushel requirement, 26.5 million bushels would be the maximum number of bushels handled by a subterminal.

Impact of subterminal system on highways

The number of bushels of grain which would have been moved by each type of vehicle over each type of highway pavement was computed for each solution. This estimate was then multiplied by the estimated cost per bushel per round trip pass for each type of vehicle to obtain an estimated total maintenance and resurfacing cost for moving grain over the highways. During the harvest season, it was assumed that grain moving up to six miles to elevators would have been hauled in 450-bushel farm wagons. Grain moved more than six miles off farms was assumed to have been hauled by 300-bushel farm trucks. After harvest, one-half of the grain was assumed to have been hauled to subterminals and elevators in 450-bushel size trucks and one-half of the grain in 450-bushel farm wagons. All grain hauled from elevators to subterminals was assumed to have been hauled in 810-bushel semi-trailer trucks.

Table 31 presents the estimated maintenance and resurfacing costs and the estimated tax revenues derived from trucks under rail options II and III

Table 30.

Estimated Bushels of Grain Handled by Subterminal Sites Selected in Optimal Solutions in Millions of Bushels for Two Rail Line Options, Single-Car, Three- to Ten-Car and Estimated One Hundred and Fifteen-Car Rates and 1969-70 Grain Prices.

	No Required Minimum Subterminal Volume		17,500,000 Bushel Minimum Volume Requirement
Subterminal Sites	Option II Keep 46 percent of 1971 rail system	Option III Keep 27 percent of 1971 rail system	Option II Keep 46 percent of 1971 rail system
Jefferson	7.2	10.4	17.9
Pocahontas	7.6	*	*
Gilmore City	9.9	*	*
Manson	14.0	*	19.9
Tara	*	18.3	*
Vincent	13.2	11.0	15.2***
Blairsburg	8.1	17.9	*
Duncombe	*	*	*
Farnhamville	17.9	*	26.5
Ellsworth	11.0	*	*
Pomeroy	*	16.0	17.6
Beaver	13.9	17.1	*
West Bend**	3.6	9.2	4.6
Albert City**	3.0	5.3	7.5
Ralston**	2.8	4.9	2.8
Goldfield**	5.4	7.5	5.4

* Not selected under this rail line option.
** Located outside of the 6½-county area.
*** Additional 2.3 million bushels assumed to be obtained from outside the 6½ county area.

Table 31.

Estimated 1980 Highway Maintenance and Resurfacing Costs and Fuel and License Taxes Paid in Selected Solutions.

Solution	Highway Maintenance and Resurfacing Costs			Fuel and License Taxes		
	From Farms	From Elevators	Total	From Farms	From Elevators	Total
Single-Car Rates only	$26,144	$ 0	$ 26,144	$59,679	$ 0	$ 59,679
Single-Car, Three to Ten-Car and Fifty-Car Rates						
a. Maintain 46 percent of rail system	38,336	34,842	73,178	79,434	51,078	130,512
b. Maintain 27 percent of rail system	41,895	44,833	86,728	84,739	85,263	171,467
Single-Car, Three to Ten-Car and One Hundred and Fifteen Car Rates						
a. Maintain 46 percent of rail system	41,630	66,163	107,793	84,258	90,486	174,744
b. Maintain 27 percent of rail system	45,613	57,813	103,426	90,078	115,564	205,642

for the single-car system, the single-car, three- to ten-car and 50-car system and for the single-car, three- to ten-car and the 115-car system. In each of these solutions, the tax revenues derived from truck movements would have exceeded the road maintenance and resurfacing costs from moving the grain over the highways by 160 to 220 percent.

Fuel consumption

Estimates were made of fuel requirements for three types of grain distribution systems. The three distribution systems were the optimum solutions based on rates for 1) the traditional single-car system; 2) the single-car, three- to ten-car shipments assembled into 50-car trains and 50-car trains loaded at subterminals; and 3) the single-car, three- to ten-car and 115-car continuous train. The results of these estimates are presented in Table 32. These estimates indicate that the 50-car solution would have used more than twice as much fuel as the single-car system. Also, the 115-car solution would have used almost three times as much fuel as the single-car solution. Further analysis indicates, however, that the reason for these differences in fuel consumption was that the single-car system would have shipped most of the corn and soybeans to Iowa and Illinois markets. The 50-car solution would have shipped 62 percent of the grain to Gulf Export and the 115-car solution would have shipped 100 percent of the grain to Gulf Export. The major difference in these large numbers was the distances the grain was hauled. Thus, it is necessary to evaluate the impact of the three systems on fuel consumption when the three systems move all the grain to the same market or markets.

Table 33 presents the fuel consumption which would be required if all three systems ship all the corn and soybeans to Gulf Export. These estimates indicate that the 50-car system would have used 503,000 gallons or 3.1 percent more fuel than the single-car system. The 115-car solution would have used 723,000 gallons or 5.6 percent more fuel than the traditional single-car solution. These increases in fuel consumption are the result of additional trucking. Thus, it appears that the differences in fuel consumption of the three systems are relatively insignificant.

Rail car fleet requirements

The maximum number of rail cars which would be needed to move the 118 million bushels of grain was computed for the traditional single-car system, for single-car,

Table 32.

Estimated Fuel Consumption for Three Grain Distribution Systems Using Rail Line Option II (46 percent) by Type of Movement in Gallons.

Grain Distribution System	Farm to Elevator or Subterminal	Elevator to Subterminal	Elevator or Subterminal to Market	Total
Traditional Single-Car System	514,574	0	4,310,545	4,825,119
Single-Car, Three- to Ten-Car and Fifty-Car System	745,638	216,629	8,820,065	9,782,392
Single-Car, Three- to Car and One Hundred and Fifteen Car System	807,477	384,404	12,754,399	13,946,280

Table 33.

Estimated Fuel Consumption for Three Grain Distribution Systems Using Rail Line Option II (46 percent) by Type of Movement to Gulf Export in Gallons.

Grain Distribution System	Farm to Elevator or Subterminal	Elevator to Subterminal	Elevator or Subterminal to Gulf Export	Total
Traditional Single-Car System	514,574	0	12,323,999	12,838,573
Single-Car, Three- to Ten-Car and Fifty-Car System	745,638	216,629	12,379,544	13,341,811
Single-Car, Three- to Ten-Car and One Hundred and Fifteen Car System	807,477	384,404	12,369,995	13,561,876

three- to ten-car and 50-car train solutions and for single-car, three- to ten-car and 115-car solutions. Rail line option I (100 percent) was used for the traditional system and rail option II (46 percent) for the multiple-car systems. The maximum car requirements were based on the estimated quantities of grain which would have been shipped to each market for each system using 1969-70 prices. A constant shipping pattern was assumed for the continuous 115-car train system and the actual shipping pattern was assumed for all other movements.

The estimated number of cars which would be needed under each system are presented in Table 34. The traditional single-car system would have required both box cars to move grain from elevators located on light lines and jumbo covered hopper cars would have been required to move grain from elevators located on heavy rail lines. This system would have required 1,584 40-foot box cars and 1,105 jumbo covered hopper cars.

The continuous 115-car train would have required only 858 jumbo covered hopper cars to move the 118 million bushels based on a constant amount shipped each month. The total car requirements for the continuous 115-car train was increased 10 percent to provide for car maintenance and repair shop time. This is only 32 percent of the traditional single-car requirements. The occasional 50-car train along with single- and three- to ten-car shipments would have required 1,842 jumbo covered hopper cars or 69 percent of the cars required under the traditional system.

Storage requirements

Additional grain storage requirements were estimated for the traditional single-car system, the single-car, three- to ten-car and 50-car system and the single-car, three- to ten-car and 115-car system. It was assumed that the 1971 storage capacity in the 6½-county area would be used as follows in 1980: 10 percent would be used for working space, 9 percent would be used to store grain which would go back to farms located in the area and 15 percent would be used to store carry-over grain from one year to another. Based on these assumptions, there would be 38,316,540 bushels of storage capacity available for commercial grain sales in 1980 from the existing 1971 total storage capacity. Based on the actual 1971 shipping pattern, 25,750,555 bushels of additional storage capacity would be needed in the 6½-county area in 1980. Assuming a constant shipping

Table 34.

Estimated Number of Rail Cars Needed to Move 118 Million Bushels of Grain to Market for Selected Grain Distribution Systems.

	Number of Rail Cars Needed			
Solution	Box	Hopper	Total	Percent of Traditional Single-Car System
Traditional single-car solution maintaining 100 percent of 1971 rail lines	1,584	1,105	2,689	100
Single-car, Three- to Ten-car and 50-car trains maintaining 46 percent of 1971 rail lines	0	1,842	1,842	69
Single-car, Three- to Ten-car and 115-car continuous trains, maintaining 46 percent of 1971 rail lines	0	858	858	32

pattern by using the continuous 115-car train, additional storage requirements in the 6½-county area would be only 17,329,620 bushels. Thus, the constant shipping pattern of the continuous train system would reduce the additional 1980 storage investment required in the 6½-county area by 8,471,100 bushels from the actual shipping pattern. The estimated increases in storage requirements are presented in Table 35.

Investment costs

Selected investment costs were estimated for three rate solutions using rail line option II (46 percent). These estimates are presented in Table 36. Estimated investments for the traditional single-car system would have been the largest of the three systems, totaling almost 76 million dollars. The single-car, three- to ten-car and 50-car system would have required an estimated 66 million dollars and the single-car, three- to ten-car and 115-car system would have required an estimated 45 million dollars. The major differences in the investment requirements are for rail cars, rail lines, and subterminals. Subterminal costs increase as the systems change to larger size multiple-car shipments. Rail car investments, however, decrease substantially under the assumption of continuous train operations. Rail line investments decrease as the size of the rail plant decreases. The $10,000,000 rail line investment cost under rail line option I would have been required just to keep the light rail lines in operation. The $5,800,000 investment under rail line option II would have been required to upgrade 105 miles of light line to carry loaded jumbo hopper cars and to rehabilitate 28 miles of heavy line which presently has restricted speed limitations because of track conditions. No additional investment would have been required to upgrade rail lines under rail option III. The decrease in rail car and rail line investments far outweigh all increases in investment requirements.

Transportation costs

Two problems were encountered in analyzing rail and rail-barge transportation based on rates. First, rail rates do not always reflect actual differences in costs. For example, differences between 3- and 50-car rates may not reflect actual differences in the cost of shipments. Secondly, barge rates fluctuate greatly, mainly due to demand for barge transportation. Therefore this phase of the study was analyzed on the basis of costs rather than rates.

Table 35.

Estimated Increases in Storage Requirements for Three Grain Distribution Systems.

Distribution System	1971 Storage Capacity for Commercial Grain Sales in Bushels	Increase over 1971 Capacity in Bushels	Percent Increase over 1971 Capacity
Traditional Single-Car System on Rail Line Option I (100 percent)	38,316,540	25,750,555	67.2
Single-Car, Three- to Ten-Car and 50-Car System on Rail Line Option II (46 percent)			
a. Elevators	27,500,460	959,048	
b. Subterminals	10,816,080	24,791,507	
c. Total	38,316,540	25,750,555	67.2
Single-Car, Three- to Ten-Car and 115-Car System on Rail Line Option II (46 percent)			
a. Elevators	29,293,020	0	
b. Subterminals	9,023,520	17,379,620	
c. Total	38,316,540	17,379,620	45.4

Table 36.

Estimated Investment Costs to Implement Three Grain Distribution Systems.

Type of Investment	Traditional Single-Car System	Single-Car, Three- to Ten-Car and 50-Car System on Rail Line Option II	Single-Car, Three- to Ten-Car and 115-Car System on Rail Line Option II
Subterminals (additional)	$ 0	$ 6,038,504	$ 7,983,162
Storage (additional)	15,115,576	15,115,576	10,201,837
810-bushel trucks (additional)	0	510,816	904,883
450-bushel trucks (total)*	93,940	213,220	250,180
300-bushel trucks (total)*	1,034,025	1,117,800	1,115,250
450-bushel wagons (total)*	2,211,984	2,997,888	3,194,606
Rail cars (total)**	46,578,500	34,077,000	15,873,000
Rail lines (additional)	10,388,172	5,841,080	5,841,080
Total	$75,422,197	$65,911,884	$45,363,998

* Total investment costs are given for trucks and wagons based on estimated needs. Additional costs could not be estimated because of lack of data on existing equipment.

** Total investment costs are given for rail cars based on estimated needs. The additional investment costs could not be computed because of the lack of data on the percent of car days used in the 6½ counties.

Using Gulf Export as the only destination, a set of solutions was obtained in which rail and barge costs were substituted for rail and barge rates. Cost solutions were obtained with the following combinations of costs in each solution:

1. Rail-barge, three- to ten-car rail shipments assembled into 50-car trains and 115-car continuous trains on rail line options II and III.
2. Rail-barge, three- to ten-car rail shipments assembled into 50-car trains and 80-car continuous trains on rail line options II and III.
3. Rail-barge, three- to ten-car rail shipments assembled into 50-car trains and 50-car occasional trains on rail line options II and III.
4. Rail-barge only on rail option I.
5. The traditional single-car system on rail option I.

Each of these solutions were based on 1969-70 grain prices. The results of these solutions are presented in Tables 37 and 38.

The traditional single-car solution which maintains the 1971 rail line system would have yielded a net joint revenue of 171.6 million dollars. This solution provides a benchmark to evaluate all other solutions.

The highest net joint revenue was obtained from a system of 115-car trains running on a continuous basis between six subterminals in the Fort Dodge area and the Gulf on rail option III which maintains only 27 percent of the 1971 rail lines. Total joint net revenue was $181,811,000 for this system which would have yielded over 10 million dollars per year or 8.7 cents per bushel more than the traditional single-car system. In this system, the 115-car continuous train would have moved 99.2 percent of the grain, while three-car shipments direct to the Gulf would have been 0.1 percent and rail-barge would have moved 0.7 percent of the 118 million bushels of grain. Revenue would have declined by $687,000 per year when the 115-car trains were combined with 46 percent of the 1971 rail lines.

Revenue would have declined 0.4 cents per bushel if 80-car trains were substituted for the 115-car trains, while continuing to maintain 27 percent of the 1971 rail lines. When 46 percent of the rail lines were maintained, the 80-car continuous train system would have yielded a net revenue of 7.8 cents per bushel over the traditional system.

Figures 22 and 23 present the flows of grain from country elevators to subterminals under the 80-car continuous train solutions. All country elevators would have received grain at harvest time. Almost all country elevators would have trucked grain to subterminals to be loaded into the 80-car trains. When 46

Table 37.

Results of the Solutions for Grain Distribution Systems Based on Estimated Costs Using Two Rail Line Options.

Item	Rail Line Option II Keep 46 Percent of 1971 Rail System		Rail Line Option III Keep 27 percent of 1971 Rail System	
	115-Car	80-Car	115-Car	80-Car
Total revenue minus all transportation, storage and variable handling costs	$182,851,000	$182,311,000	$182,551,000	$182,130,000
Less annual subterminal investment costs	$1,217,000	$1,045,000	$918,000	$922,000
Less annual rail line maintenance and upgrading costs	$510,000	$510,000	$-178,000	$-178,000
Total joint net revenue	$181,124,000	$180,756,000	$181,811,000	$181,386,000
Number of subterminals in 6½-county area	8	9	6	8
Increase in total joint net revenue over 1971 system*	$9,523,000	$9,155,000	$10,210,000	$9,785,000
Increase in total joint net revenue over 1971 system in cents per bushel	8.1	7.8	8.7	8.3

* Total joint net revenue for the traditional single-car system was $171,600,000.

Table 38.

Results of the Solutions for Grain Distribution Alternatives Based on Estimated Costs Using Three Rail Line Options.

Item	Rail-barge Option I Maintain 1971 Rail System	50-Car Option II Keep 46 Percent of 1971 Rail System	50-Car Option III Keep 27 Percent of 1971 Rail System
Total revenue minus all transportation, storage and variable handling costs	$177,488,000	$179,110,000	$178,462,000
Less annual subterminal investment costs	0	603,000	440,000
Less annual rail line maintenance and upgrading costs	1,145,000	510,000	-178,000
Total joint net revenue	176,343,000	177,997,000	178,200,000
Number of subterminals in 6½-county area	0	8	7
Increase in total joint net revenue over 1971 system	4,742,000	6,396,000	6,599,000
Increase in total joint net revenue over 1971 system in cents per bushel	4.0	5.4	5.6

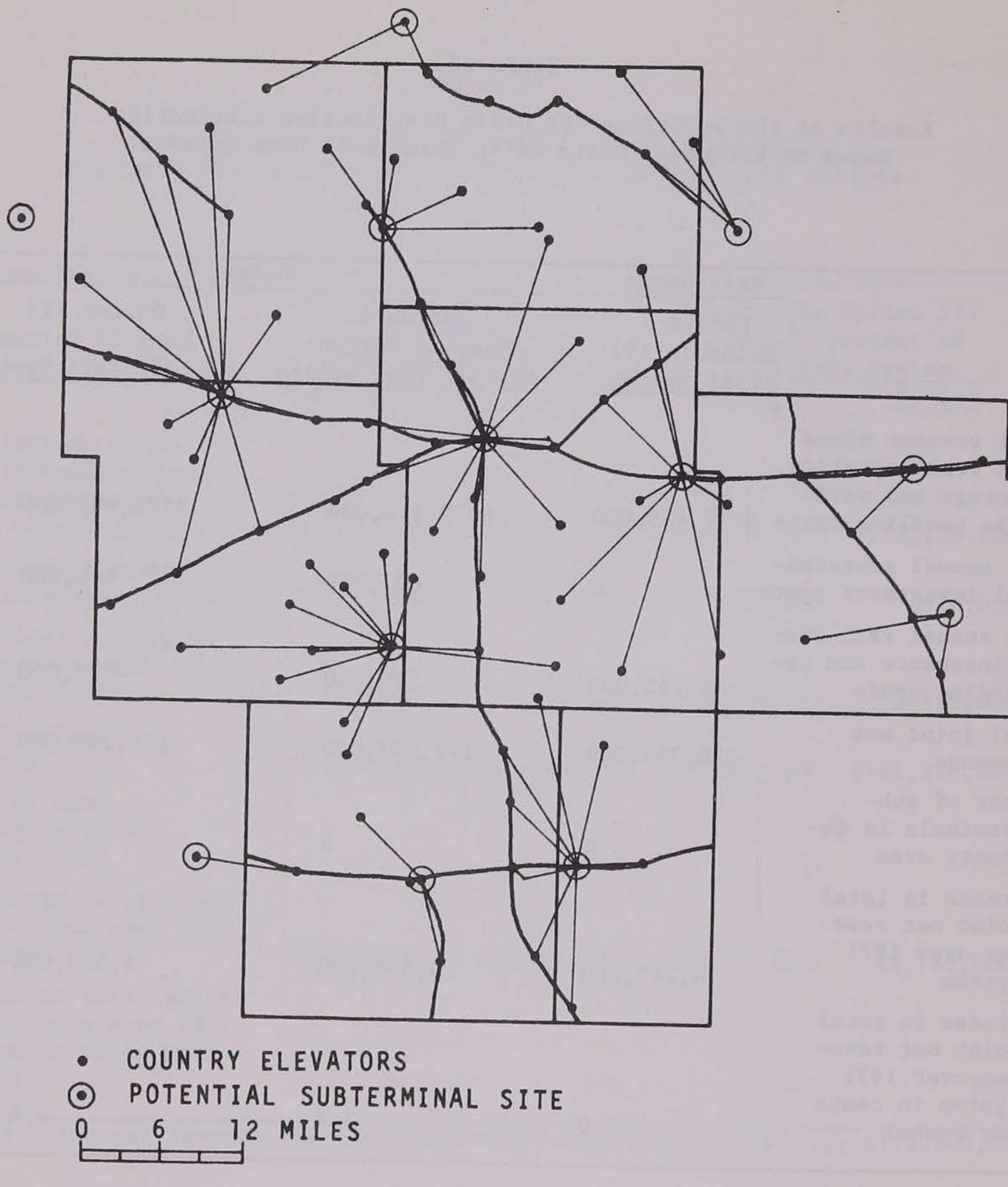


Figure 22.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Rail-barge, Three- to Ten-Car and 80-Car Cost System, for 1969-70 Grain Prices and Rail Line Option II, Fort Dodge Area.

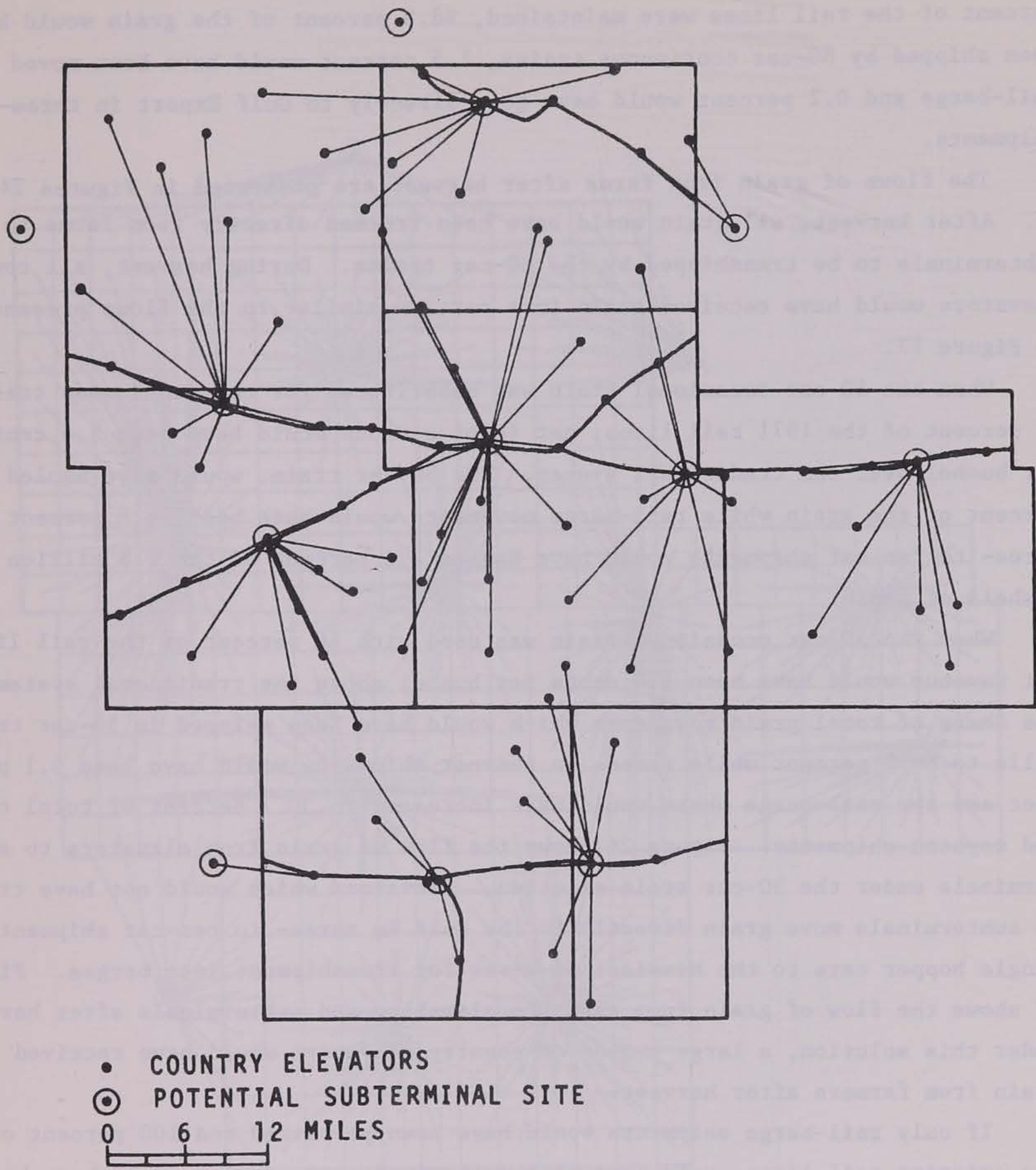


Figure 23.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Rail-barge, Three- to Ten-Car and 80-Car Cost System, for 1969-70 Grain Prices and Rail Line Option III, Fort Dodge Area.

percent of the rail lines were maintained, 98.3 percent of the grain would have been shipped by 80-car continuous trains, 1.5 percent would have been moved by rail-barge and 0.2 percent would have gone directly to Gulf Export in three-car shipments.

The flows of grain from farms after harvest are presented in Figures 24 and 25. After harvest, all grain would have been trucked directly from farms to subterminals to be transhipped by the 80-car trains. During harvest, all country elevators would have received grain in a pattern similar to the flows presented in Figure 17.

When the 50-car occasional train was substituted for the continuous train on 27 percent of the 1971 rail lines, net joint revenue would have been 5.6 cents per bushel over the traditional system. The 50-car train would have hauled 81.1 percent of the grain while rail-barge movements would have been 16.8 percent and three- to ten-car shipments would have hauled 2.1 percent of the 118 million bushels of grain.

When the 50-car occasional train was used with 46 percent of the rail lines, net revenue would have been 5.4 cents per bushel above the traditional system. The share of total grain movements which would have been shipped in 50-car trains falls to 66.2 percent while three- to ten-car shipments would have been 3.1 percent and the rail-barge share would have increased to 30.7 percent of total corn and soybean shipments. Figure 26 shows the flow of grain from elevators to subterminals under the 50-car train solution. Elevators which would not have trucked to subterminals move grain directly to the Gulf in three- to ten-car shipments or single hopper cars to the Mississippi River for transhipment into barges. Figure 27 shows the flow of grain from farms to elevators and subterminals after harvest. Under this solution, a large number of country elevators would have received grain from farmers after harvest.

If only rail-barge shipments would have been permitted and 100 percent of the existing rail lines would have been maintained, net revenue would have been 4.0 cents per bushel above the traditional system but 4.7 and 4.3 cents per bushel under the optimal 115-car and 80-car continuous train solutions.

<u>Grain shipments to the West Coast</u>

The distribution of corn and soybeans to the eleven markets was based on actual monthly market prices at each market less transportation costs to each market. West Coast markets were not included as a possible market because of

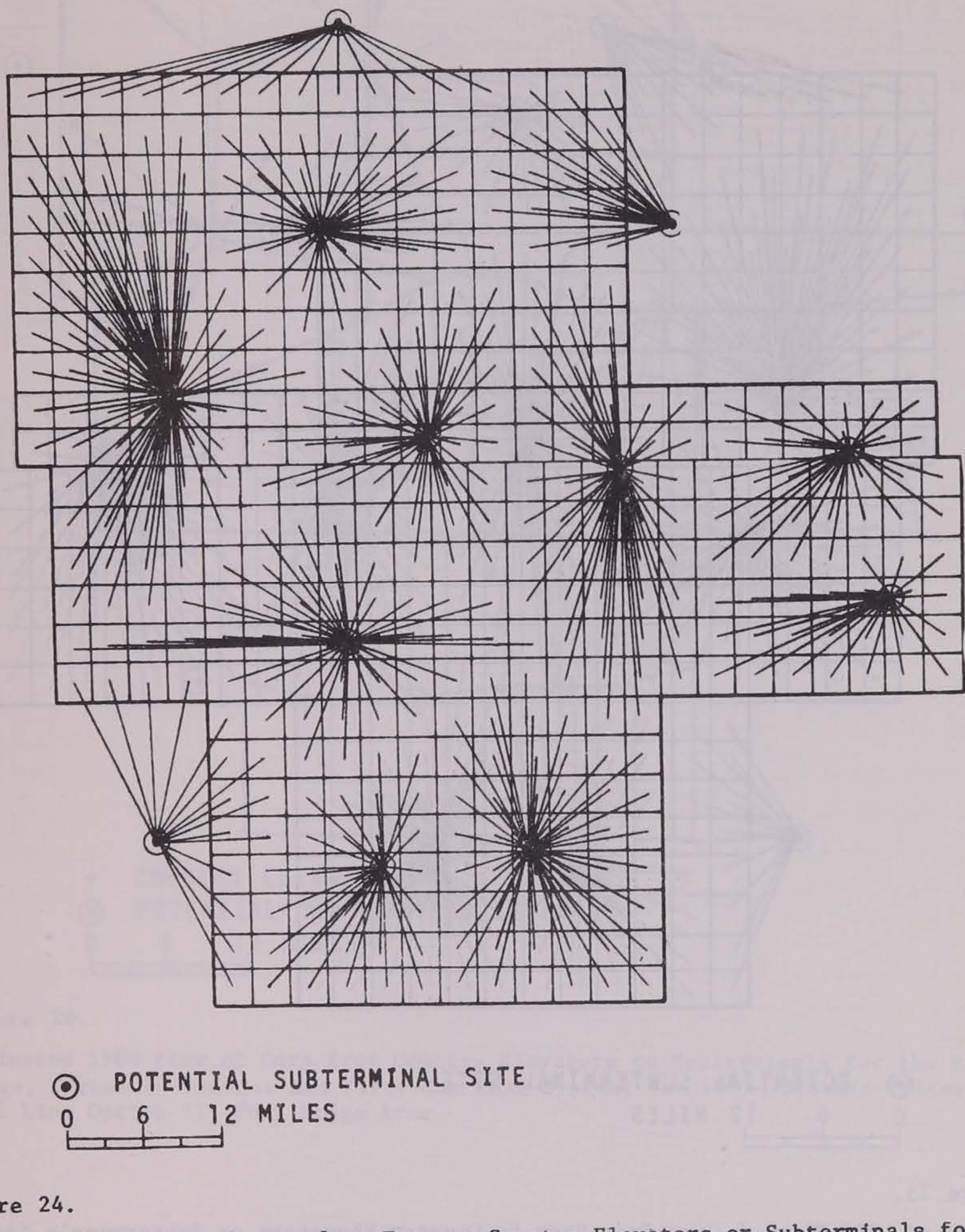


Figure 24.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Rail-barge, Three- to Ten-Car and 80-Car Cost System, for 1969-70 Grain Prices and Rail Line Option II, During Non-Harvest Months, Fort Dodge Area.

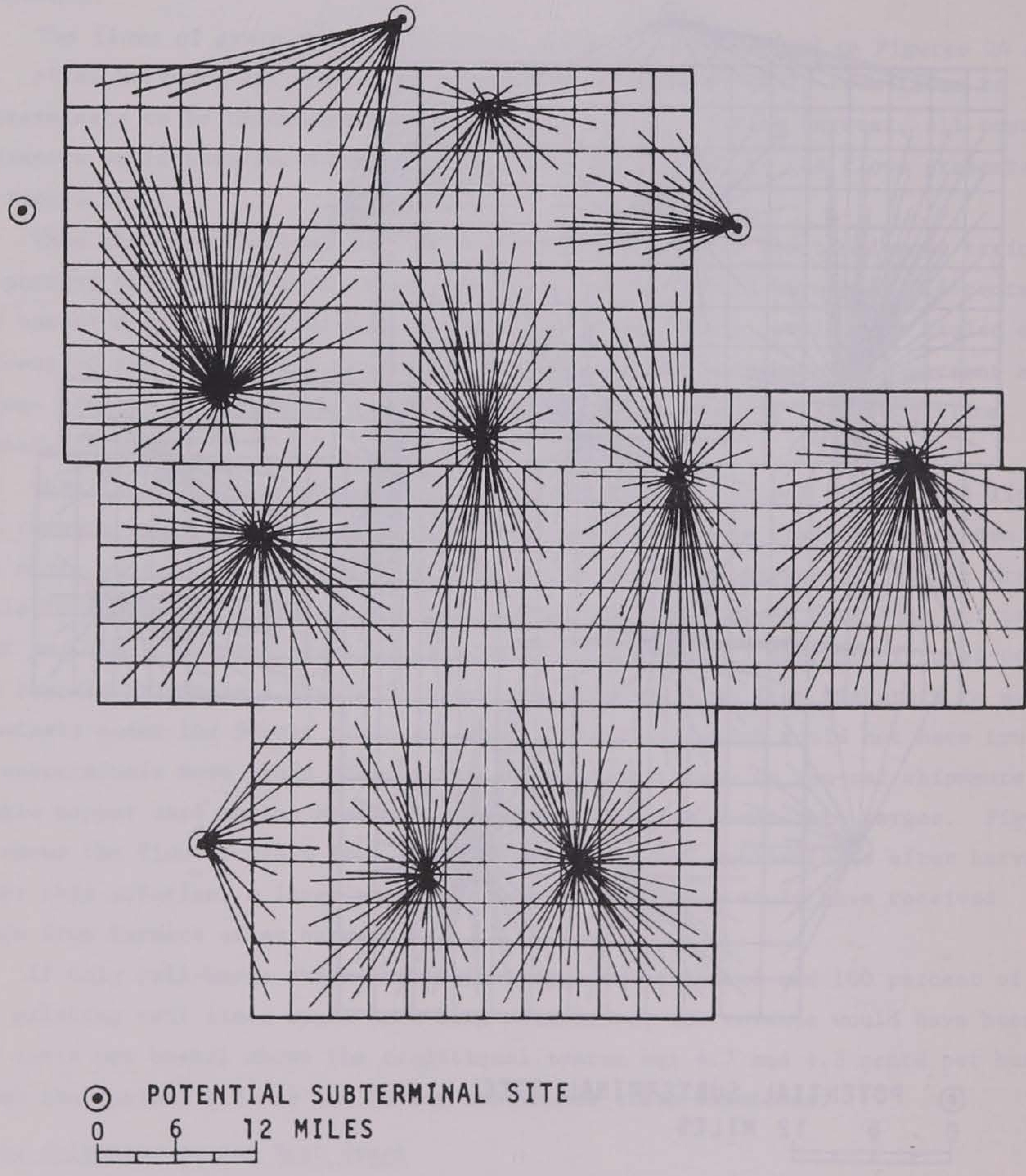


Figure 25.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Rail-barge, Three- to Ten-Car and 80-Car Cost Systems, for 1969-70 Grain Prices and Rail Line Option III, During Non-Harvest Months, Fort Dodge Area.

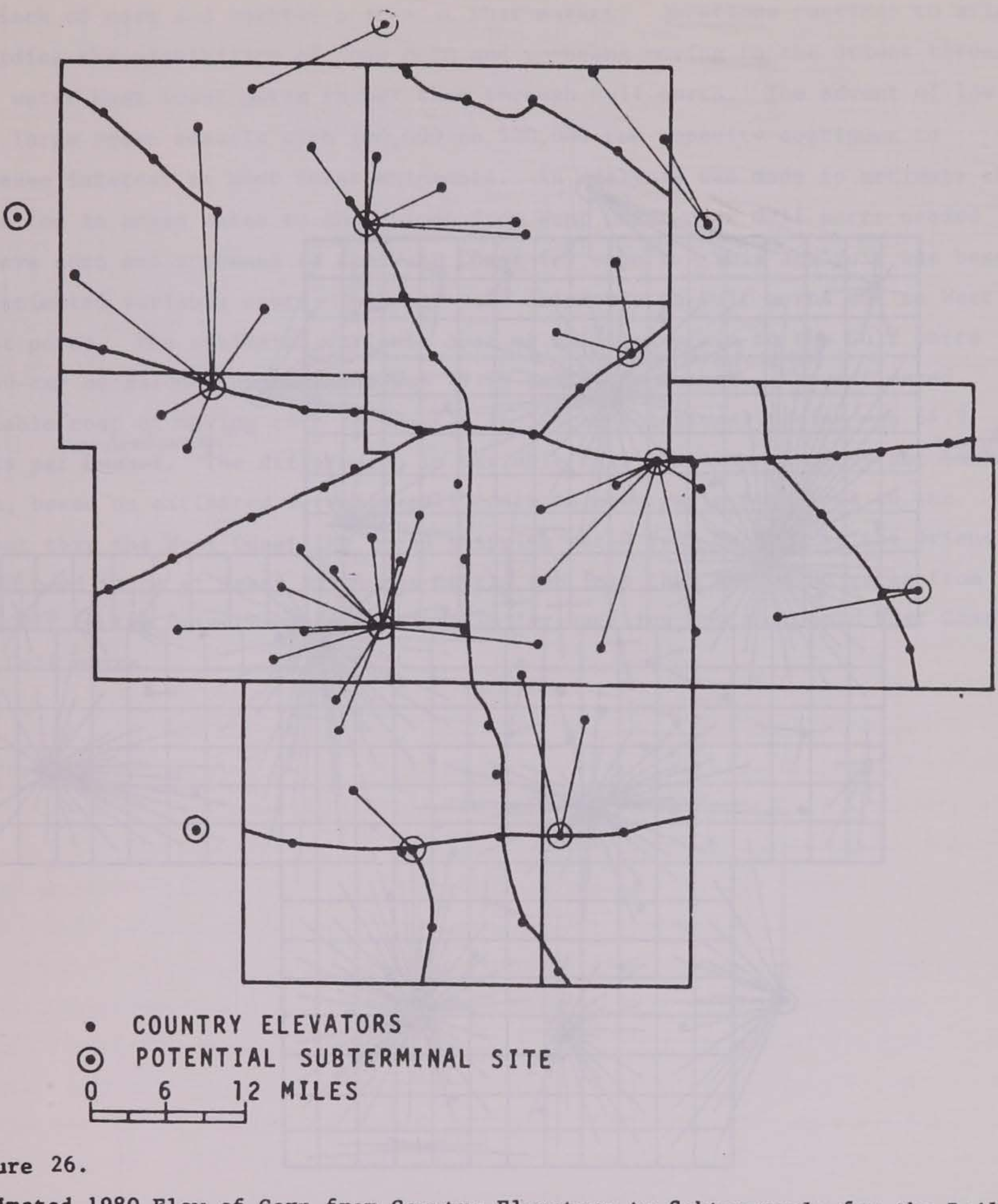


Figure 26.

Estimated 1980 Flow of Corn from Country Elevators to Subterminals for the Rail-barge, Three- to Ten-Car and Fifty-Car Cost System, for 1969-70 Grain Prices and Rail Line Option II, Fort Dodge Area.

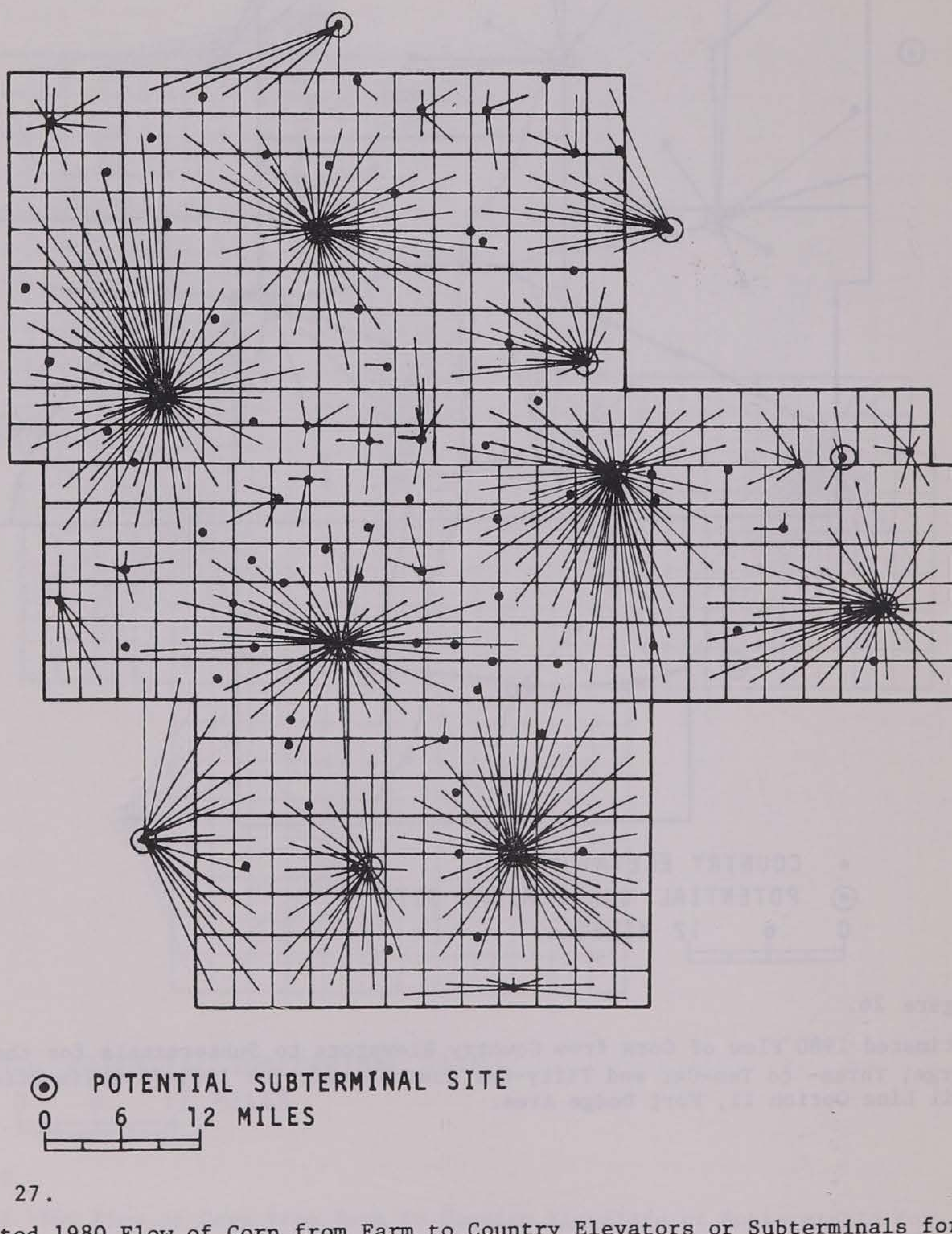


Figure 27.

Estimated 1980 Flow of Corn from Farm to Country Elevators or Subterminals for the Rail-barge, Three- to Ten-Car and Fifty-Car Cost System, for 1969-70 Grain Prices and Rail Line Option II, During Non-Harvest Months, Fort Dodge Area.

the lack of corn and soybean prices at that market. Questions continue to arise regarding the possibility of Iowa corn and soybeans moving to the Orient through deep water West Coast ports rather than through Gulf ports. The advent of low cost large ocean vessels with 100,000 to 500,000 ton capacity continues to increase interest in West Coast shipments. An analysis was made to estimate the reduction in ocean rates to the Orient from West Coast over Gulf ports needed to move corn and soybeans to the West Coast for export. This analysis was based on estimated variable costs of 50-car rail shipments to Gulf ports and to West Coast ports. The estimated variable cost of shipping grain to the Gulf ports by 50-car occasional unit trains was 39.89 cents per ~~bushel~~ hundredweight. The estimated variable cost of moving corn to Seattle in 50-car occasional trains was 64.9 cents per ~~bushel~~ hundredweight. The differences in variable rail cost was 25 cents per ~~bushel~~ hundredweight. Thus, based on estimated variable rail costs to move grain from Iowa to the Orient thru the West Coast the ocean shipping rates from Seattle to the Orient would need to be at least $~~9.84~~ 5.50 per metric ton less than the ocean rates from the Gulf to the Orient. This assumes similar handling costs at both West Coast and Gulf ports.

Chapter V
Summary and Conclusions

The problem

Midwestern grain shippers historically have faced transportation problems. Recently, these problems have reached crisis proportions. In January 1973, a Central Iowa grain elevator manager stated, "We have the ownership and contracts for almost two million bushels of grain. In the past four weeks we have moved 32 cars by rail, one half being open top coal cars. At this rate, it will take two years to move our inventory. Iowa farmers are desperate to move this cash grain."

Recent changes in the supply of and demand for corn and soybeans and innovations in grain harvesting and transportation have compounded the problems of the grain distribution system. In the past decade, U.S. corn and soybean production have increased more than 50 percent. During the same time, corn and soybean exports have almost tripled, requiring more grain to be shipped longer distances. Shifts in harvesting techniques have enabled farmers to move huge quantities of grain to market in short periods of time, forcing elevator operators to either ship large quantities of grain in short periods of time or store hundreds of thousands of bushels out on the streets.

In an attempt to provide more transportation capacity, railroads have issued multiple-car tariffs to capture the efficiencies of faster turnaround times and to reduce delays in loading, switching and unloading cars.

In addition to multiple-car shipments, railroads are also encouraging the use of larger size rail cars for the transport of grain. The jumbo covered hopper car capable of hauling up to 3,300-3,500 bushels of grain is rapidly replacing the 2,000 bushel capacity box car. The number of 40-foot box cars in the United States has declined from 563,470 in 1960 to 212,000 cars in 1973. During the same period of time, covered hopper cars increased from 64,255 to 186,219 cars.

However, such innovations as multiple-car shipping rates and the use of jumbo covered hopper cars have not solved the grain transportation problems. In fact, these innovations tend to complicate the problems of some elevator operators.

Substantial investments in loading facilities are required to load large multiple-car shipments. Many of the rail lines in grain producing regions were located and designed to facilitate early 1900 technology. Some of the rail lines require upgrading and/or repair if they are to handle the heavy hopper cars and multiple-car trains. The decline in the number of 40-foot box cars and encouragement of multiple-car shipments by rail carriers, places the elevators located on a light branch rail line at a considerable disadvantage.

Railroad officials contend that the large number of rail lines in grain producing regions preclude an efficient rail system. Although there seems to be a general agreement among railroad officials that too many branch lines are in existence, there is considerable difference of opinion of how many and which lines should be closed.

There is considerable uncertainty regarding the benefits of the alternative grain transportation systems. There is a lack of knowledge of where investments should be made to gain the maximum benefits of these systems. Neither the pricing systems nor regulator policies are adequately designed to coordinate or facilitate the industry adjustments needed to insure an efficient physical distribution system and provide for the general transportation needs of an expanding grain industry.

Summary of the results

The purpose of the research was to find which grain distribution system would yield the highest net income in a 6½-county area around Fort Dodge, Iowa. Net income was defined as the gross income from the sale of the projected 1980 volume of 118 million bushels of grain delivered to one or more of 11 markets, minus all transportation from farm to market, non-farm storage, variable handling and facility investment costs and rail line maintenance and upgrading costs.

Transportation alternatives considered include the traditional single-car rail system, multiple rail car shipments of 3, 50, 80, and 115 cars, truck, truck-barge and rail-barge. It was assumed that subterminals would be required to load shipments of 50 cars or more. Also, alternative rail line options were considered: these included maintaining the 1971 rail system, maintaining and upgrading 100 percent, 46 percent and 27 percent of the 1971 rail lines to permit trains with jumbo hoppers to travel at least 35 miles per hour.

Computer programs were developed to determine the most efficient system of grain distribution. Data required in the programs included the 118 million bushels of grain expected to be sold outside the area in 1980, prices from the 11 markets now served by the area, as well as handling costs and transportation rates which are presently available in Iowa or Illinois, and the rail line options. The computer solutions determined what marketing and shipping system would produce the most net revenue for the 6½ counties, using various combinations of all these alternatives.

Generally, the highest net revenue was obtained by using a subterminal system to assemble large quantities of grain into multiple-car shipments. The optimum number of such subterminals varied, depending on the rate structure and amount of rail maintained in each analysis.

All of the evaluations are not directly comparable because some of the evaluations were based on 1969-70 grain prices and others were based on 1970-71 grain prices. Also, some evaluations were based on rates to all markets and others were based on estimated costs to the Gulf. In general, the following alternative systems are ranked in descending order in terms of total net revenue:

1. One hundred and fifteen-car continuous trains handling 99.2 percent of all the grain with 3- to 10-car rail shipments assembled into 50-car trains and rail-barges hauling the balance of the grain, operating on 27 percent of the 1971 rail system.
2. Eighty-car continuous trains handling 99 percent of all the grain with 3- to 10-car rail shipments assembled into 50-car trains and rail-barges hauling the balance of the grain, operating on 27 percent of the 1971 rail system.
3. One hundred and fifteen-car continuous trains handling 99 percent of all the grain with 3- to 10-car rail shipments assembled into 50-car trains and rail-barges hauling the balance of the grain, operating on 46 percent of the 1971 rail system.
4. Eighty-car continuous trains hauling 98 percent of the grain with 3- to 10-car rail shipments assembled into 50-car trains and rail-barges hauling the balance of the grain, operating on 46 percent of the 1971 rail system.

5. Occasional 50-car trains hauling 81 percent of all the grain with 3- to 10-car rail shipments assembled into 50-car trains hauling 17 percent of the grain and rail-barges hauling 2 percent of the grain, operating on 27 percent of the 1971 rail line system.
6. Occasional 50-car trains, handling 66 percent of the grain with 3- to 10-car rail shipments assembled into 50-car trains handling 3 percent of the grain and rail-barges hauling 31 percent of the grain, operating on 46 percent of the 1971 rail line system.
7. Occasional 50-car trains handling 91 percent of all the grain, 3- to 10-car rail shipments assembled into 50-car trains and single-car shipments handling the balance of the grain, operating on 27 percent of the 1971 rail system.
8. Occasional 50-car trains handling 88 percent of all the grain, 3- to 10-car rail shipments assembled into 50-car trains and single-car shipments hauling the balance of the grain, operating on 46 percent of the 1971 rail system.
9. Occasional 50-car trains hauling 81 percent of all the grain, 3- to 10-car rail shipments assembled into 50-car trains and single-car shipments hauling the balance of the grain, operating on 100 percent of the 1971 rail line system.
10. Rail-barge operating on 100 percent of the 1971 rail line system.
11. The traditional single-car system operating on 100 percent of the 1971 rail line system.

Based on rates, the highest net revenue was obtained from a subterminal system using 115-car trains operating continuously between Gulf ports and six subterminals within the 6½-county area and maintaining only 27 percent of the 1971 rail lines in the study area. This system yielded 9.2 million dollars more per year or 7.8 cents a bushel, than the traditional single-car system. Revenue would have declined 0.4 cent per bushel when 46 percent of the 1971 rail lines were maintained and eight subterminals load the 115-car trains. This system would require only 858 covered hopper cars or 32 percent as many as the traditional system to move the 118 million bushels of grain because of car use efficiencies in multiple-car shipments.

Under the optimum system with the 115-car trains, all of the grain would be moved to the Gulf ports. By contrast, when single-car rates were used, the most net revenue would have been obtained when only 9 percent of the grain moved to the Gulf and two-thirds of it went to Chicago. This indicates the multiple-car shipments open up the Gulf export markets to Iowa.

A system using 27 percent of the 1971 rail lines over which movements of single-car shipments, 3- to 10-car shipments assembled into 50-car trains, and 50-car trains loaded at ten subterminals located within the area, yielded a net revenue of 5.1 cents per bushel over the traditional single-car method. Revenue is 4.9 cents per bushel over the traditional method when 46 percent of the 1971 rail lines were maintained and 3.7 cents per bushel over the traditional system when the entire 1971 rail system was maintained. This combination system of single-car, 3- to 10-car and 50-car trains when using 46 percent of the rail system would require 31 percent fewer cars than the traditional single-car system to move the 118 million bushels of grain.

When 1970-71 grain prices were used to allocate grain among markets, the optimal single-car, 3- to 10-car and 50-car train solution would have used rail option III. Net revenue would have declined 0.3 cent per bushel if rail line option II (46 percent) would have been used. Net revenue would have declined another 0.5 cent per bushel if rail line option I would have been used. Gulf export would have received 42 percent of the grain under 1970-71 prices compared to 9 percent of the grain under the traditional single-car system using 1969-70 prices. Evidently, the rate reductions on multiple-car export shipments more than compensated for the higher domestic grain prices.

Two problems were encountered in analyzing rail and rail-barge transportation rates. First, rail rates may not always reflect actual differences in cost. For example, differences between 3- and 50-car rates may not reflect actual differences in the cost of shipment. Secondly, barge rates fluctuate greatly mainly due to demand for barge transportation. Therefore, one phase of the study was analyzed on the basis of costs, rather than rates.

Using rail and barge costs to the Gulf as the only destination, the study indicated the highest net revenue would have been obtained from a system of 115-car trains running continuously between elevators and the export ports. For the greatest return, 99 percent of the grain moving out of the area would have moved directly to the export ports from six subterminals using 27 percent of the 1971 rail lines. The rail-barge combination would have moved only one percent of the grain. Net revenue would have been 8.7 cents per bushel higher under this type of movement than under the single-car system using all the 1971 rail lines.

When 80-car trains are substituted for the 115-car train and eight subterminals are located on 27 percent of the 1971 rail lines, revenue would have been 8.3 cents per bushel above the traditional system. Under this system, about one percent of the grain would have moved by rail-barge.

When 50-car trains were loaded from eight subterminals located within the 6½ counties in addition to single- and three-car shipments moving directly from country elevators located on 27 percent of the 1971 rail lines, net revenue would have been 5.6 cents per bushel above the traditional single-car system. Optimally, about 16 percent of the grain would have moved by rail-barge under this system with single-cars supplying barges and multiple-car shipments going direct to the Gulf. When 46 percent of the rail lines are maintained, revenue would have been 5.2 cents per bushel above the single-car system. Under this system, almost 30 percent of the grain would have moved by rail-barge, about 5 percent by 3-car shipments and two-thirds by 50-car trains. No grain would have moved by box cars because the estimated box car - barge costs were about four cents per bushel higher than the rail hopper car - barge costs and the cost of moving grain to Gulf export was 7.4 cents per bushel higher in single box cars than in single hopper car shipments.

A solution based only on rail-barge costs would have yielded 4.0 cents per bushel more than the 1971 traditional system but 4.7 cents per bushel less than the 115-car solution.

Other major findings of this study were:

1. All existing elevators remained in business under all rail line options and rate structures, although those on abandoned lines would have had to modify their operations.
2. Under the 115-car continuous train system and rail line option II, reduced transportation rates would represent 89 percent of the increased net revenue. Reduced rail line costs would represent 11 percent of the increased net revenue. Under rail line option III, reduced transportation rates would represent 82 percent of the increased net revenue and reduced rail maintenance would represent 18 percent of the increased net revenue. Assuming an adequate supply of covered hopper cars, it would be expected that much of the increased net revenue from greater utilization of multiple-car rates would be passed on to the shippers.
3. Storage requirements increased 67 percent over 1971 for the traditional

single-car system and for the single-car, 3- to 10-car and occasional 50-car system, but only 45 percent for the continuous train system. The difference in storage requirements is a function of shipping patterns rather than size of shipment.

4. Investment requirements to handle the projected 1980 volume of grain would have been $75,000,000 for the traditional single-car system. Investment would be $66,000,000 for the single-car, 3- to 10-car and 50-car system. The single-car, 3- to 10-car and 115-car system would require only $45,000,000 of investment to handle the 1980 projected volume. The reduction in rail car and rail line investments far outweigh all increases in investment requirements.
5. Normally, there is a cost advantage in building additional storage at country elevators and subterminals rather than on the farm because of greater utilization of equipment at the elevator.
6. Taxes paid by trucks hauling grain from farms to elevators and subterminals, and from elevators to subterminals exceeded the cost of road maintenance and resurfacing resulting from the movement of the grain. This analysis, however, was only for short distance movements within the 6½-county area.
7. Fuel consumption for shipping the 118 million bushels of corn and soybeans to the Gulf for export would have increased only 5.6 percent for the 115-car continuous train system over the traditional system. Fuel consumption increased only 3.1 percent for the 50-car system to Gulf export over the single-car system because of increased truck and wagon movements to subterminals.

This study is specifically for the 6½-county area surrounding Fort Dodge, Iowa, a heavy cash grain producing area located about 200 miles from the Mississippi River. Results are directly applicable only to that area and under the assumptions made in the study, although they may be used to provide insights into grain distribution efficiency elsewhere. In addition, the assumptions made regarding rail abandonment consider only the cost and net revenue for corn and soybeans shipped from the area. Obviously, in rail abandonment decisions consideration must be given to other shipments on these lines, although the only major product that appears to be affected in this area is fertilizer. If policy objectives are not solely economic, these non-economic variables must be considered in decision making.

With the introduction of the multiple-car rates in Iowa in 1971, the traditional single-car system began changing to alternative nine (page 119). Alternative nine is the system operating in the 6½-county area at the present time.

The highest revenues would have been obtained from either the 80-car and 115-car continuous trains operating on 27 percent of the 1971 rail line system. Thus, this study indicates the 115-car or 80-car continuous train system is the best alternative in terms of net revenue, reduced investment in equipment and facilities and in capacity to move large quantities of grain with minimum congestion in the entire system. This high net revenue system is something of an "ideal" or model system. It ignores the realities of separate ownership and competition. Therefore, it should be regarded as a goal or target. Realistically, moving 50 percent to 60 percent of the grain, rather than 99 percent, in continuous trains, would be a dramatic accomplishment in the area.

The system which actually develops will depend on what rail abandonment actually occurs and the extent to which the grain industry, carriers and farmers are willing to work together to accomplish such a goal. Basically, these people must weigh the benefits of the model system against the problems of individual adjustments and cooperation, continuing transportation problems and the risk of rail abandonment and over-investing in facilities if each unit decides to go its own way in an unplanned system.

To move toward reaching the higher net revenue goals of the first or second system, two intermediate phases could be implemented. The first phase might be to improve the present operations of alternative nine. The second phase might be to abandon parts of the 1971 rail line system and upgrade other rail lines to approximate rail line option II (46 percent). This latter phase would facilitate the introduction of 80- to 115-car continuous trains which result in substantial improvements in net revenue over alternative nine. It should be emphasized here that the analysis in this study included only corn and soybeans. It is possible that if other commodities such as fertilizer would have been included in the analysis, rail option II (46 percent) could be a better alternative than rail option III.

Institutional problems in implementing alternatives

A number of possible institutional problems could arise in implementing the selected alternatives. Among these possible problems is the difficulty of expediting interline movements of the occasional 50-car train and the continuous 80- and 115-car trains. At the present time, the unit train movements are most successful on railroads which have direct lines to the selected markets. In this case, the originating railroad controls the train all the way from the origin to the destination and return. The average turnaround time of unit train movements to the Gulf over a 12-month period for one railroad operating direct to the Gulf from the 6½-county area was 8.9 days. This included 48 hours of free unloading time. On the other hand, unit train movements which interline with other railroads require substantially longer turnaround times. In part, this difficulty arises because the interlining railroad will sometimes take part of the multiple-car shipment to fill out a scheduled train. The remaining cars must then wait for another through train to the destination. Frequently, multiple-car shipments that arrive at the destination as a unit are broken up in a similar manner on the return trip causing longer turnaround times because of extra days required to accumulate the 50 cars for loading at the origin. Thus, a major institutional problem in implementing the selected alternatives is lack of coordination among the interlining railroads in keeping the 50 or 80 or 115 cars together as a unit. Conceptually, there is no reason why the 50, 80, or 115 cars cannot remain together as a unit for the entire trip. Using the same set of locomotives to power the unit is possible and desirable from the standpoint of faster turnaround times. Interline problems have been solved in moving other commodities. For example, continuous trains now moving steel from a western origin to a midwestern destination are being handled by three rail lines in route without the delays normally encountered in interline traffic. Two of the three railroads involved in this movement operate in the 6½-county area.

The interline problem could also restrict the number of buyers who could receive grain from the 6½-county area on a unit train basis. Typically, the originating railroad prefers to write the tariff so receiving elevators on the direct line movement can receive the grain. If the interlining problem were solved, more receivers could bid for the grain and thereby increase the willingness of shippers to guarantee annual volumes.

A second possible problem could arise over recent Interstate Commerce Commission rules limiting the number of covered hopper cars which railroads are permitted to place in unit train service.

A third possible problem on unit train movements is the present condition of main line track in Iowa. While there is uncertainty of the impact of unit grain train movements on the maintenance of way, there is little doubt that some main line track in Iowa will need substantial maintenance to avoid delays from derailment and speed limitation.

Turning to institutional problems arising at the origins, unwillingness of both country elevator and subterminal operators to work together could delay the implementation of the selected alternatives. Country elevator operators fear that the subterminal system will place them in an inferior bargaining position through reduced marketing alternatives. Subterminal operators have displayed some evidence that they may try to force country elevators out of business through bidding procedures. Thus, a cooperative effort by both country elevator and subterminal operators is needed to enable them to work together to gain the benefits of the selected systems.

Present and near future investment in subterminal facilities could also create problems in moving to the higher income alternatives. The solutions in this study indicate that a larger number of subterminals is optimum for alternatives eight and nine than for alternatives one through four. Once the optimal number of subterminals for alternative nine are constructed, there will be resistance to changing to other higher revenue alternatives because of the fixed investments; and the income potential of the other alternatives will be lowered because of the costs associated with duplicate investments. As of July 1973, there were nine subterminals with 50-car loading capacity either planned or constructed within the 6½ county area. Moreover, there were at least four subterminals with 25-car loading capacity. A planning effort needs to be undertaken with railroad participation to avoid either duplicate or unneeded investments.

Problems could also arise at the port destination. Some port elevators do not have sufficient rail siding to handle 80-car or 115-car unit trains. Thus, some delays would be encountered by breaking up the units for unloading unless the amount of siding is increased. There would need to be a high degree of cooperation from the receiver to promptly unload the grain and enable the shipper to meet the volume requirements of continuous trains. In short, there would need to be a higher degree of cooperation or integration among shippers, carriers and receivers to enable the continuous train system to achieve its net income potential. Substantial experimentation and cooperation would be needed from both railroads and barge companies to gain the possible benefits from rail-barge movements.

Another problem arises regarding the export ports. Use of 115-car continuous trains, basically is a system of booking transportation in advance. Essentially a contract is made with the railroad to supply a train for a period of time continuously between the subterminals and the Gulf ports. In addition to the concern about the ports being able to handle the grain physically, there is an equal or greater concern with an available market outlet.

Consequently there is a need to make available to other markets rates similar to the 115-car rates available to Gulf export from Illinois. However, such rates need to be made available to export elevators within an area, other than those located on a given rail line. And there is a need to have similar rates to other areas so shippers have the opportunity to gain the efficiency of these systems in moving grain to other markets. The concept of booking transportation in advance is not new. It currently is used on barge shipments and to some extent on the 50-car occasional trains which must be scheduled for a minimum of five consecutive turns. However, the expanded use of even larger continuous trains on this basis obviously would require additional flexibility.

There is concern among leaders in rural communities of the possible disastrous impact of railroad abandonment in their communities. The results of this research under the assumptions stated, suggest that none of the alternative grain distribution systems evaluated would force country elevators out of business if their railroad line would be abandoned. The growth of these elevators would undoubtedly be reduced but farmers would continue to be served by these facilities. On the other hand, the cost of not moving to alternatives one through eight is reduced income and continuing grain transportation problems.

Chapter VI
Suggestions for Further Research

The purpose of this research was to find which grain distribution system would yield the highest net income in a 6½-county area around Fort Dodge. The optimum grain transportation system is interdependent with the flows of other products into and out of an area. However, this study did not consider the impact of the flows of other products. The product which is most likely to influence the optimum grain distribution system is fertilizer. Fertilizer is particularly important because it flows into many of the same locations from which grain is shipped. Furthermore, the flow of fertilizer will influence the optimum rail line network. Thus, one very important extension of this research is to incorporate other products, particularly fertilizer, into the research and to analyze other rail line network options. A second extension of this research would be to expand the size of the area studied to a statewide or multi-state area. This extension would provide a more comprehensive analysis of the impact of railroad abandonment on grain distribution systems. It would also permit an analysis of rail-barge distribution systems from areas closer to main waterways than the Fort Dodge area.

In this study, the analysis of rail-barge combinations was limited to single rail car-single barge movements. A third extension of this research would be an analysis of the potential of multiple rail car-multiple barge intermodal shipments.

This study did not include the costs of alternative grain distribution systems at the final markets. A fourth possible extension of this research would be to analyze the impact of alternative distribution systems on the final markets. This could be extended to the possible impact of alternative systems on the export potential of corn and soybeans.

The cost coefficients used for grain handling facilities were constant marginal costs. A fifth possible extension of this research would be to incorporate economies of size of grain handling facilities.

A sixth area for additional research on alternative grain distribution systems would be to refine the estimates of single- and multiple-car rail costs. A starting point would be the Interstate Commerce Commission 1970 Cost Scales. However, these scales do not include the costs of multiple-car rail shipments. Individual

cost studies of actual multiple-car shipments would be useful in refining these cost estimates. Associated with this extension is the need to estimate the impact of multiple-car shipments on rail line maintenance.

A seventh area for additional research is to estimate the impact of the 34-car rule for abandonment on the achievement of high income alternatives identified in this study.

An eighth area for additional research is to analyze the economics of other possible grain distribution systems, such as containers on flat cars.

Finally, there is a need to develop and establish data collection procedures to maintain relevant data needed for the analysis of distribution systems for agricultural products.

Appendix A

Plant and Rail Line Location Model

Definition of symbols and mathematical functions

The definition of symbols and/or mathematical functions are presented in this section that relate to: 1) the spatial structure of the grain distribution system; 2) the spatial and temporal flow of grain; 3) total transportation costs; 4) total grain handling costs at country elevators; 5) total grain handling costs at subterminal elevators and; 6) total revenue. All symbols defined in this section are needed in stating the objectives of the two stage multi-period transhipment plant-location model. Other symbols are defined as they are used.

The time horizon over which alternative rail-based grain distribution systems are evaluated extends from 1971 to 1980. Symbols, unless stated otherwise, represent the crop year 1980. Time, which varies from $t = 1, 2, \ldots, T$, denotes months where the first month of the crop year is October.

Symbols are classified as exogenous, endogenous, or both exogenous and endogenous. The value of exogenous variables or parameters are determined outside of the model and taken as given. The value of endogenous variables are determined by the model. Variables are classified as both exogenous and endogenous if they are predetermined for one time period and then become endogenously determined thereafter. Let:

en = the set of endogenous variables and

ex = the set of exogenous parameters and variables.

Symbols in this section are identified as exogenous, endogenous, or exogenous and endogenous by placing ex, en, or ex and en within parentheses at the end of each definition.

Spatial structure of the grain distribution system

The following symbols denote the predetermined location of final destinations and country elevators. Potential sites for subterminals and alternative rail line systems are also identified. Various combinations of rail line systems and subterminal numbers and locations form the spatial structure of

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This model is based on George W. Ladd's "Fifth Variation on a Theme by Stollsteimer" Journal Paper No. J-7591 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa.

alternative rail-based grain distribution systems. Let:

ϵ = element of

L_j = location of j^{th} final destination; j = 1,2,...,J; (ex).

$L1_h$ = h^{th} plant site for a country elevator or elevator of type one; h = 1,2,...,H; (ex).

$L2_i$ = i^{th} plant site for subterminal or elevator of type two; i = 1, 2,...,I; (ex).

r = r^{th} rail line network; r = 1,2,...,R. A rail line network represents one feasible combination of rail lines in a region. The locational pattern of a rail line system may be altered by abandoning or upgrading rail lines existing at the beginning of the planning horizon, 1971; or by constructing new rail lines. Potential subterminal sites depend upon the rail line network since, by definition, a subterminal ships grain by rail in multiple-car trains; (ex).

λ_{mnr} = alternative locational patterns for subterminals and rail line systems, where m denotes the m^{th} locational pattern for n plants of type two given the r^{th} rail line network; $n \leq I$; and m = 1,2,..., [I!/n!(I-n)!]; (ex).

For example, if r denotes a rail line network that permits subterminals to be established at 30 subterminal sites; then, λ_{11r} denotes the location of 1 subterminal given r. The subterminal may be located at one of 30 possible sites; and m = 1 denotes the location, e.g. $L2_4$, for the one subterminal. One locational pattern for 3 plants given r may be identified by $\lambda_{1,3,r}$ and include subterminals located at sites $L2_6$, $L2_8$, and $L2_9$. $\lambda_{2,3,r}$ identifies three plants with a different locational pattern than $\lambda_{1,3,r}$.

Country elevators exist at the beginning of the planning horizon, 1971.

Some country elevators may become subterminals, in which case the plant site of a country elevator is the same as the plant site for a subterminal, $L1_k = L2_i$. Whenever $i \in \lambda_{mnr}$ and $L1_i = L2_i$, the range of country elevators $(h = 1,2,\ldots,H)$ excludes $L1_k$. Thus, $h \in \lambda_{mnr}$ and $i \in \lambda_{mnr}$ denote country elevators and subterminals included in the grain distribution system of λ_{mnr}.

Spatial and temporal flow of grain

The following symbols denote the flow of grain from origins to final destinations over time and space. The monthly supply of grain from each farm is predetermined. The flows, or temporal and spatial routings, of grain from origins to final destination are determined endogenously by the model.

All symbols representing the flow of grain, marginal transportation costs, elevator capacity, and prices follow a general format. Variable or parameter indices are placed within parentheses. The first index denotes commodities and is followed by a semicolon. The second index represents origins and has a time subscript to denote various months. The third index represents country elevators and has two time subscripts to identify months of receiving and load out. The fourth index represents subterminals and also has two time subscripts to identify months of receiving and load out. The difference between receiving and load out represents storage period. The last index represents final destinations and has a time subscript to denote various months. Let:

$X(\varnothing;g_t\ h_{ss'},\ i_{uu'},\ j_v)$ = quantity of commodity $\varnothing$ shipped from origin g time t through $L1_h$ and/or $L2_i$ and received at destination j in time v. Quantity received at $L1_h$ in time s is stored from s to s'. Quantity received at $L2_i$ in time u is stored from u to u'. Either v = u' or v = s'. And, either t = s or t = u; (en).

$X(\varnothing;g_t\ldots)$ = predetermined supply of commodity $\varnothing$ at origin g in time t; (ex).

$$g = 1,2,\ldots,G$$

$t = 1,2,\ldots,T$

$s = 1,2,\ldots,Z.$

$X(s;g_t\ h_{t.}\ ..)$ = quantity of commodity s shipped from origin g in time t and received during time t at plant type 1 located at $L1_h$; (en).

$X(s;g_t.i_{t.}.)$ = quantity of s shipped from origin g in time t and received during time t at plant type 2 located at $L2_i$; (en).

$X(s;.h_{t.}\ ..)$ = $\sum_g X(s;g_t h_{t.}\ ..)$; quantity of s shipped from all origins in time t to plant type 1 located at $L1_h$; (en).

$X(s;.h_{.s'}..)$ = quantity of s shipped from plant type 1 located at $L1_h$ at time s'; (en).

$s' = t,t+1,\ldots,T.$

$X(s;.h_{.s'}i_{s'.}.)$ = quantity of s shipped from plant type 1 located at $L1_h$ during time s' to plant type 2 located at $L2_i$; (en).

$X(s;..i_{t.}.)$ = $\sum_g X(s;g_t.i_{t.}.) + \sum_h X(s;.h_{.t}i_{t.}.)$; quantity of s shipped from all origins in time t and from all plants type 1 in time t to plant type 2 located at $L2_i$; (en).

$X(s;..i_{.u'}.)$ = quantity of s shipped from plant type 2 located at $L2_i$ at time u'; (en).

$u' = u,u+1,\ldots,T.$

$X(s;.h_{.s'}.j_{s'})$ = quantity of s shipped from plant type 1 located at $L1_h$ during time s' to destination j and received during time s'; (en).

$X(s;..i_{.u'}j_{u'})$ = quantity of s shipped from plant type 2 located at

$L2_i$ during time u' to destination j and received during time u'; (en).

$X(ø;...j_{s'})$ = $\sum_h X(ø;.h_{.s'}.j_{s'}) + \sum_i X(ø;..i_{.s'}j_{s'})$; quantity of ø shipped from all plants of type 1 in time s' and from all plants of type 2 in time s' to destination j; (en).

= quantity received at destination j time s'.

$X(ø;.h_{ss'}..)$ = quantity of ø received at $L1_h$ during time s and stored until the beginning of time s'. When s = s', grain is received and loaded out immediately requiring no storage capacity at $L1_h$; (en).

$X(ø;..i_{uu'}.)$ = quantity of ø received at $L2_i$ during time u and stored until the beginning of time u'. When u = u', grain is received and loaded out immediately requiring no storage capacity at $L2_i$; (en).

<u>Total transportation costs</u>

The total transportation cost function accounts for 1) the annual cost of constructing, maintaining, and upgrading rail lines; and 2) the marginal costs of shipping grain from origins to destinations. The marginal costs of transportation represent the least costly mode of transport for a given month, distance, and load out facility. Subterminals, for example, may ship by rail to final destitions in multiple-car trains. Country elevators may ship by single car rail, truck, or truck-barge depending on their location and time of year. Farms ship grain to elevators using tractor-wagon or truck depending, again, upon distance and month.

The minimum annual cost of establishing and maintaining a given rail line option is based on the additional costs of upgrading, maintaining, and/or abandoning branch rail lines existing at the beginning of the planning horizon 1971, within the study area. The costs of maintaining the road network are included in the marginal costs of transporting grain by truck.

The total transportation cost function is presented by equation 1.

$$(1)\quad TTC = \gamma_r + \sum_t \sum_s \Big\{ \sum_g \sum_h C(s;g_t h_{t.}..) \; X\,(s;g_t h_{t.}..) + \sum_g \sum_i C(s;g_t . i_{t.}.) \; X\,(s;g_t . i_{t.}.) + \sum_h \sum_i C(s;.h_{.t} i_{t.}.) \; X\,(s;.h_{.t} i_{t.}.) + \sum_h \sum_j C(s;.h_{.t} . j_t) \; X\,(s;.h_{.t} . j_t) + \sum_i \sum_j C(s;..i_{.t} j_t) \; X\,(s;..i_{.t} j_t) \Big\} \;;\; h, i \in \lambda$$

where:

γr = minimum annual cost of establishing and maintaining rail line option r; (ex).

$C(s;g_t h_{t.}..)$ = marginal cost of shipping commodity s to $L1_h$ from origin g in time t; (ex).

$C(s;g_t . i_{t.}.)$ = marginal cost of shipping commodity s to $L2_i$ from origin g in time t; (ex).

$C(s;.h_{.s'} i_{s'.}.)$ = marginal cost of shipping to $L2_i$ from $L1_h$ in time s'; (ex).

$C(s;.h_{.s'} . j_{s'})$ = marginal cost of shipping to final destination j from $L1_h$ time s'; (ex).

$C(s;..i_{.u'} j_{u'})$ = marginal cost of shipping to destination j from $L2_i$ time u'; (ex).

Equation 1 contains six terms on the right hand side of the equality sign. The first term is defined above, the second and third terms denote the variable costs of shipping grain from origins to country elevators and subterminals, the fourth and fifth terms denote the variable costs of shipping grain from country elevators to subterminals and final destinations, and the last term denotes the variable cost of shipping grain from subterminals to final destinations.

Grain handling costs: country elevators

The cost function for handling grain at country elevators accounts for the marginal operating and maintenance costs of receiving and drying, storing, and loading out grain using facilities existing in 1971. Marginal operating and maintenance costs include items such as labor, elevator repairs, fuel, power, office supplies, and insurance on grain.

At the beginning of the planning horizon, 1971, H (H = 87) country elevators were in existence. Receiving, drying, and load out capacities of country elevators are somewhat flexible and depend upon the number of hours per day the elevator wishes to handle grain. Storage capacity, however, is different. To increase storage capacity, additional storage facilities need to be constructed. Thus, it is assumed that by the end of the planning horizon, 1980, country elevators may need to expand storage facilities, but not receiving, drying, and load out facilities, to accommodate the projected increase in grain supply.

The cost function for handling grain at country elevators, therefore, accounts for not only marginal operating and maintenance costs of handling grain with facilities existing in 1971, but also the total costs of expanding storage capacity when necessary beyond 1971 capacity.

Total costs of expanding storage facilities of a country elevator include an annual average cost of adjustment; and a marginal cost of expanding storage capacity. The annual average costs of adjustment reflect the cost of various items that are required to expand storage facilities. Such items include the purchase of additional land, conveyor systems used to move grain from receiving pits to storage bins, aeration and heat detection equipment, and the cost of redesigning elevator layout. Some costs of adjustment may also result from the disruptions of elevator operations as elevator facilities are altered to permit the expansion of storage capacity.

The marginal cost of expanding storage capacity reflects the costs of constructing additional silos or storage bins. Grain silos and storage bins may be constructed for different volumes of grain, and do not encounter the indivisibilities of construction inherent in the annual average costs of adjustment as described in the preceding paragraph.

Since marginal storage expansion costs are incurred only after 1971 storage capacity has been exceeded, the total handling cost function for country elevators requires a switching rule. Before storage capacity is exceeded, the marginal cost of storing grain includes only the marginal operating and maintenance costs of using storage existing in 1971. Once capacity has been reached, additional bushels stored incur a marginal storage cost which includes both a marginal operating and maintenance cost, and a marginal cost of expanding storage capacity.

The total handling cost function for country elevator Ll_h is presented by equation 2:

$$\text{(2)}\quad THC\,(h.) = \alpha(h.) + \sum_{s}\sum_{s} \beta R(s;h_{s.}.)\; X(s;.h_{s.}..) + \sum_{s}\sum_{s=1}^{T}\sum_{s'=s}^{T} \alpha\,\beta S(s;h_{ss'}.)\; X(s;.h_{ss'}..) + \sum_{s}\sum_{s'} \beta L(s;h_{.s'}.)\; X(s;.h_{.s'}..)$$

where

$$\text{(3)}\quad \alpha(h.) = \begin{cases} S1 \text{ if } X(.;.h_{s\bar{s}'}..) > K(h_{ss'}.) \\ \text{or} \\ 0 \text{ otherwise} \end{cases}$$

and

$$\text{(4)}\quad \alpha\,\beta\,S(s;h_{ss'}.) = \begin{cases} \beta\,S(s;h_{ss'}.) + S2 \text{ if } X(.;.h_{s\bar{s}'}..) > K(h_{ss'}.) \\ \text{or} \\ \beta\,S(s;h_{ss'}.) \text{ otherwise.} \end{cases}$$

The symbols used in equations 2, 3, and 4 are defined as follows: Let

$\alpha(h.)$ = minimum annual average cost of adjustment required to expand storage capacity of an existing country elevator located at Ll_h; (ex).

S1 = minimum annual average cost of adjustment required to expand storage capacity of an existing country elevator; (ex).

$K(h_{ss'},.)$ = storage capacity at Ll_h at the beginning of month s'. Storage capacity is predetermined for s' = 1. Storage capacity beyond the first month may be expanded and, thus, becomes endogenous for s' = 2,3,...,T; (ex and en).

$$X(.;.h_{s\bar{s}'},..) = \sum_{\text{s}} \sum_{s=1}^{s'} X(\text{s};.h_{ss'+1}..)$$

= total volume of grain in storage at Ll_h at the beginning of time s'; (en).

$\beta R(\text{s};h_{s.}.)$ = marginal operating and maintenance cost of receiving and drying commodity s at Ll_h in time s; (ex).

$\alpha\beta S(\text{s};h_{ss'},.)$ = marginal cost of storing commodity s at Ll_h from time s to s'; (ex).

$\beta S(\text{s};h_{ss'},.)$ = marginal operating and maintenance costs of storing commodity s at Ll_h from time s to s'; (ex); and

S2 = marginal cost of expanding storage facilities at a country elevator; (ex).

$\beta L(\text{s};h_{.s'},.)$ = marginal operating and maintenance cost of loading out commodity s at Ll_h in time s'; (ex).

Grain handling costs: subterminal

The total cost function for handling grain at a subterminal is similar to the total cost function for handling grain at a country elevator. The grain handling cost function of a subterminal accounts for the marginal operating and maintenance costs of receiving and drying, storing, and loading out grain.

Unlike country elevators, however, subterminals were not in existence at the beginning of the planning horizon, 1971. To establish a subterminal, therefore, either an existing country elevator has to expand facilities to meet the minimum capacity requirements of a subterminal or a completely new subterminal must be constructed.

The minimum capacity requirements for handling facilities at a subterminal differ from the capacity requirements of existing country elevators. Subterminals must be designed to load out multiple-car trains. Subterminals require more rail siding and switches than country elevators. A trackmobile or vehicle to move the rail cars on the rail siding, and special load out legs, spouts, and conveyor belts designed to rapidly load out grain are also required at a subterminal.

Minimum receiving and drying capacity at subterminals also differs from that at country elevators. Subterminals receive grain from not only farmers, but also from country elevators. Receiving dumps, scales, truck hoists, and conveyor systems at subterminals must, therefore, be designed to handle 810 bushel grain semi-trailer trucks from country elevators as well as the smaller tractor-wagon and 300 bushel grain trucks used by farmers.

Total expansion cost of storage facilities is treated the same for subterminals as for country elevators. No minimum storage capacity is required. Additional storage capacity may be constructed according to the total storage expansion cost function specified for country elevators. Total storage capacity of subterminals and country elevators required at the end of the planning horizon, 1980, is endogenously determined by the model.

Total costs of establishing minimum capacities for receiving, drying, and loading out grain at a subterminal depends upon the receiving, drying, and load out capacities existing at the site where the subterminal is to be established. The total cost functions for establishing receiving, drying, and load out facilities for a subterminal are of the form:

(5) $\alpha R(.i) = R1 + R2 \left[K(.\bar{i}_{u.}) - K(.i_{u.})\right]$; (ex).

= minimum annual total cost of establishing receiving facilities at $L2_i$; if $K(.\bar{i}_{u.}) > K(.i_{u.})$; or

= zero if $K(.\bar{i}_{u.}) \leq K(.i_{u.})$

(6) $\alpha D(.i) = D1 + D2 \left[K(1;.\bar{i}_{u.}) - K(1;.i_{u.})\right]$; (ex).

= minimum annual total cost of establishing drying facilities at $L2_i$; if $K(1;.i\bar{}_{u.}) > K(1;.i_{u.})$; or

= zero if $K(1;.i\bar{}_{u.}) \leq K(1;.i_{u.})$

(7) $\alpha L(.i) = L1 + L2 \left[K(.i_{.\bar{u}'}) - K(.i_{.u'})\right]$; (ex.)

= minimum annual total cost of establishing load out facilities

at $L2_i$; if $K(.i_{.\bar{u}'}) > K(.i_{.u'})$; or

= zero if $K(.i_{.\bar{u}'}) \leq K(.i_{.u'})$

where R1, D1, and L1 denote the minimum annual average costs of adjustment required to establish receiving, drying, and load out facilities for a subterminal. R1, D1, and L1 are determined exogenously and reflect the indivisibilities of constructing, receiving, drying, and load out facilities, and account for various start-up costs such as designing elevator layout and training of new personnel.

R2, D2, and L2 denote the marginal costs of establishing receiving, drying, and load out facilities for a subterminal. R2, D2, and L2 are determined exogenously and reflect the cost of those items influenced by the difference between required and existing capacity.

Required and existing capacities for receiving, drying, and loading out grain are denoted by the following symbols:

$K(.i\bar{}_{u.})$ = minimum receiving capacity required to receive grain from country elevators and farmers at $L2_i$; (ex).

$K(1;.i\bar{}_{u.})$ = minimum drying capacity required to dry corn received from country elevators and farmers at $L2_i$; (ex).

$K(.i_{.\bar{u}'})$ = minimum load out capacity required at $L2_i$ to load out multiple car trains; (ex).

$K(.i_{u.})$ = receiving capacity at $L2_i$ existing at the beginning of the planning horizon, 1971; (ex),

$K(1;.i_{u.})$ = drying capacity at $L2_i$ existing at the beginning of the planning horizon; (ex).

$K(.i_{.u'})$ = load out capacity at $L2_i$ existing at the beginning of the planning horizon; (ex).

The total annual average cost of establishing a subterminal located at $L2_i$ may be, therefore, defined by equation 8:

$$(8) \quad \alpha(.i) = \alpha R(.i) + \alpha D(.i) + \alpha L(.i) + S1$$

S1 is defined for a country elevator and denotes the minimum annual average cost of adjustment required to establish storage capacity at an elevator; (ex). Equation 9 presents the total handling cost function for a subterminal located at $L2_i$:

$$(9) \quad THC(.i) = \alpha(.i) + \sum_{s} \sum_{u} \beta R(s;.i_{u.}) X(s;..i_{u.}.) + \sum_{s} \sum_{u=1}^{T} \sum_{u'=u}^{T} \alpha\beta S(s;.i_{uu'}) X(s;..i_{uu'}.) \sum_{s} \sum_{u'} \beta L(s;.i_{.u'}) X(s;..i_{.u'}.)$$

where

$\beta R(s;.i_{u.}.)$ = marginal operating and maintenance cost of receiving and drying commodity s at $L2_i$ in time u; (ex);

$$(10) \quad \alpha\beta S(s;.i_{uu'}) = \begin{cases} \beta S(s;.i_{uu'}) + S2 & \text{if } X(.;..i_{\overline{uu'}}.) > K(.i_{uu'}); \\ \text{or} & \\ \beta S(s;.i_{uu'}) & \text{if } X(.;..i_{uu'}.) \leq K(.i_{uu'}) \end{cases}$$

= marginal cost of storing commodity s at $L2_i$ from time u to u'; (ex);

and

$\$S(ж;.i_{uu'})$ = marginal operating and maintenance cost of storing commodity ж at $L2_i$ from time u to u'; (ex); and

S2 = marginal cost of expanding storage facilities at a subterminal; (ex); and

$$X(.;..i_{uu'}^{-}.) = \sum_{ж} \sum_{u=1}^{u'} X(ж;..i_{uu'+1}.)$$

= total volume of grain in storage at $L2_i$ at the beginning time u'; (en) and

$K(.i_{uu'})$ = storage capacity at $L2_i$ at the beginning of month u'. Storage capacity is predetermined for u' = 1. Storage capacity beyond the first month may be expanded and, thus, become endogenous for u' = 2,3,...,T: (ex and en).

The last term in the total handling cost function, equation 9, represents the total operating and maintenance cost of loading commodity ж at $L2_i$ in time u' where:

$\$L(ж;.i_{.u'})$ = marginal operating and maintenance cost of loading out commodity ж at $L2_i$ in time u'; (ex).

Total revenue

Grain is shipped from subterminals and country elevators to final markets. For each month and destination there exists a demand price for commodity ж. Revenue obtained from each market, for each month, is determined by multiplying the volume of grain received at each final market by the price existing at that destination. Total revenue is the sum of all revenues obtained over all months and destinations. Let:

$$(11)\quad TR = \sum_{ж} \sum_{j} \sum_{v} \pi(ж;...j_v) \left[\sum_{h \epsilon \lambda_{mnr}} X(ж;.h_{.v}.j_v) + \sum_{i \epsilon \lambda_{mnr}} X(ж;..i_{.v}j_v) \right]$$

where

$\pi(ß;...j_v)$ = price of commodity ß at final destination j in time v; (ex).

Mathematical statement

The uses of the model are to determine 1) n, the number of subterminals, 2) $h \in \lambda_{mnr}$, the number of country elevators, 3) $K(h_{sT}.)$ and $K(.i_{uT})$, the storage capacity of country elevators, $L1_h$, and subterminals, $L2_i$, 4) λ_{mnr}, the rail line system and locational pattern for subterminals, $L2_i$, and, 5) $X(g_t h_{ss'} i_{uu'} j_v)$, the flow of grain from origins g to final destinations, L_j, over time and space to maximize Π, the joint net revenue of producers where:

$$(12)\ \Pi = \left\langle \sum_{ß} \sum_{j} \sum_{v} \pi(ß;...j_v) \left[\sum_{h} X(ß;.h_{.v}.j_v) + \sum_{i} X(ß;..i_{.v}j_v) \right] \right\rangle$$

$$- \left\langle \sum_{ß} \left\{ \gamma_r + \sum_{g} \sum_{t} \left[\sum_{h} C(ß;g_t h_{t.}..)\ X(ß;g_t h_{t.}..) + \right. \right. \right.$$

$$\left. \sum_{i} C(ß;g_t.i_{t.}.)\ X(ß;g_t.i_{t.}.) \right]$$

$$+ \sum_{h} \sum_{s'} \left[\sum_{i} C(ß;.h_{.s'}i_{s'}.)\ X(ß;.h_{.s'}i_{s'}.) + \right.$$

$$\left. \sum_{j} C(ß;.h_{.s'}.j_{s'})\ X(ß;.h_{.s'}.j_{s'}) \right]$$

$$\left. \left. + \sum_{i} \sum_{j} \sum_{u'} C(ß;..i_{.u'}j_{u'})\ X(ß;..i_{.u'}j_{u'}) \right\} \right\rangle$$

$$- \sum_{h} \left\langle \sum_{h_ß} \left[\alpha(h.) + \sum_{s} BR(ß;h_{s.}.)\ X(ß;.h_{s.}..) \right. \right.$$

$$+ \sum_{s=1} \sum_{s'=s} \alpha\beta S(ß;h_{ss'}.)\ X(ß;.h_{ss'}..)$$

$$\left. \left. + \sum_{s'} BL(ß;h_{.s'}.)\ X(ß;.h_{.s'}..) \right] \right\rangle$$

$$- \sum_{i} \left\langle \sum_{ß} \left[\alpha(.i) + \sum_{u} \beta R(ß;.i_{u.})\ X(ß;..i_{u.}.) \right. \right.$$

$$+ \sum_{u=1} \sum_{u'=u} \alpha\beta S(s;.i_{uu'})\, X(s;..i_{uu'}.)$$

$$\left. \left. + \sum_{u'} \beta L(s;.i_{.u'})\, X(s;..i_{.u'}.) \right] \right\rangle ; \; h, i \in \lambda_{mnr} .$$

Simplifying, equation 12 may be stated:

$$(13) \quad \pi = TR - TTC - \sum_{h \in \lambda_{mnr}} THC(h.) - \sum_{i \in \lambda_{mnr}} THC(.i) .$$

Symbols enclosed by the first set of $\langle\rangle$ on the right hand side of the equality sign in equation 12; and TR in equation 13 represent total revenue as specified by equation 11. Terms within the second set of $\langle\rangle$ in equation 12, and TTC in equation 13 represent total transportation costs as specified by equation 1. Terms within the third and fourth sets of $\langle\rangle$ in equation 12, and THC(h.) and THC(.i) in equation 13 represent the cost of handling grain at country elevator h located at $L1_h$ and subterminal i located at $L2_i$ as specified by equations 2 and 9.

The objective function defines joint net revenue as the income received at final destinations minus grain transportation and grain handling costs at elevators. Total transportation costs include the minimum annual cost of upgrading and maintaining alternative rail line network options; and the variable transportation costs from farm to elevator, country elevator to subterminal and to terminal market, and subterminal to terminal market.

Total handling costs at country elevators and subterminals include the marginal operating costs of receiving and drying, storing, and loading out grain. Total handling costs also include the annual costs of establishing and/or expanding elevator facilities.

Equation 11, or 12, is maximized subject to the following material balance equations and prerequisite conditions for elevator capacity expansion:

(14) $$\sum_{h} X(\mathbf{s};g_t h_{t.}..) + \sum_{i} X(\mathbf{s};g_t.i_{t.}.) = X(\mathbf{s};g_t...)$$

Equation 14 states: the total supply received at elevators in period t directly from origins equals the supply at origins in period t.

(15) $$\sum_{g} X(\mathbf{s};g_t h_{t.}..) = X(\mathbf{s};.h_{t.}..)$$

Equation 15 states: the total supply received at $L1_h$ in time t equals the supply shipped to $L1_h$ from all origins in time t.

(16) $$\sum_{i} X(\mathbf{s};.h_{.s'}i_{s'}.) + \sum_{j} X(\mathbf{s};.h_{.s'}.j_{s'}) = X(\mathbf{s};.h_{.s'}..)$$

Equation 16 states: the supply received at subterminals and terminal markets from $L1_h$ in time s' equals the supply shipped from $L1_h$ in time s'.

(17) $$\sum_{g} X(\mathbf{s};g_t.i_{t.}.) + \sum_{h} X(\mathbf{s};.h_{.t}i_{t.}.) = X(\mathbf{s};..i_{t.}.)$$

Equation 17 states: the total supply received at $L2_i$ in time u equals the supply shipped to $L2_i$ from all origins and all country elevators in time t.

(18) $$\sum_{j} X(\mathbf{s};..i_{.u'}j_{u'}) = X(\mathbf{s};..i_{.u'}.)$$

Equation 18 states: the supply received at all terminal markets from $L2_i$ in time v equals the supply shipped from $L2_i$ in time u.

(19) $$\sum_{h} X(\mathbf{s};.h_{.s'}.j_{s'}) + \sum_{i} X(\mathbf{s};..i_{.s'}j_{s'}) = X(\mathbf{s};...j_{s'})$$

Equation 19 states: the supply received at terminal market L_j in time v equals the supply shipped from country elevators and subterminals to L_j in time s'.

(20) $$\sum_{s=1}^{s'} X(\mathbf{s};.h_{s.}..) - \sum_{t=1}^{s'} X(\mathbf{s};.h_t..) = X(\mathbf{s};.h_{s's'}..)$$

Equation 20 states: amount stored at $L1_h$ at the beginning of month s' equals cumulative receipts minus cumulative shipments to s'.

(21) $$\sum_{s=1}^{T} X(s;.h_{s.}..) = \sum_{s' \geq s}^{T} X(s;.h_{.s'},..)$$

Equation 21 states: total receipts at $L1_h$ equals total outshipments.

(22) $$\sum_{u=1}^{u'} X(s;..i_{u.}..) - \sum_{t=1}^{u'} X(s;..i_{.t}..) = X(s;..i_{u'u'},..)$$

Equation 22 states: amount stored at $L2_i$ at the beginning of month u' equals cumulative receipts minus cumulative shipments to u'.

(23) $$\sum_{u=1}^{T} X(s;..i_{u.}.) = \sum_{u' \geq u}^{T} X(s;..i_{.u'}.)$$

Equation 23 states: total receipts at $L2_i$ equals total outshipments.

(24) $$\sum_{t}\sum_{g} X(s;g_t...) = \sum_{v}\sum_{j} X(s;...j_v)$$

Equation 24 states: total supply equals total receipts at terminal markets.

(25) $\alpha(h.) = S1;$

(26) $\alpha(.i) = S1 + \alpha R(.i) + \alpha D(.i) + \alpha L(.i);$

and,

(27) $\alpha\beta S(h.) = \beta S(h.) + S2;$

(28) $\alpha\beta S(.i) = \beta S(.i) + S2;$

if $X(.;.h_{s\bar{s}'},..) > K(h_{ss'},.)$ and

$X(.;..i_{s\bar{s}'}.) > K(.i_{ss'})$ for all h and i; or

(29) $\alpha\ (h.) = 0;$

(30) $\alpha\ (.i) = \alpha R(.i) + \alpha D(.i) + \alpha L(.i);$

and

(31) $\alpha\beta S(h.) = \beta S(h.);$

(32) $\alpha\beta S(.i) = \beta S(.i);$

if $X(.;.h_{s\bar{s}'},..) \leq K(h_{ss'},.)$ and

$X(.;..i_{s\bar{s}'},.) \leq K(.i_{ss'})$ for all h and i.

Equations 25 to 32 present conditions necessary to permit expansion of elevator capacity; i.e., excess capacity in one elevator precludes another elevator from expanding. Equations 25, 26, 27, and 28 are operative if no elevator has excess storage capacity in time s'. Equations 28, 29, 30, and 31 are operative if any elevator has excess storage capacity in time s'.

(33) $X(s;g_t h_{ss'}, i_{uu'}, j_v) \geq 0$ for all s, g, h, i, j, t, s, s', u, u', and v.

Equation 33 states: all commodity flows over time and space are non-negative.

Depending on the locational pattern of subterminals and rail lines, some country elevators may be the site of a subterminal. Thus, $L1_h \notin h = 1,2,...,H$ when $L1_h = L2_i$; h, i ε λ_{mnr}.

Method of solution

As previously discussed, Stollsteimer developed a method of solution for plant location models with no transhipment and Ladd extended the initial model to include a single stage of transhipment. The following method incorporates procedures developed by Stollsteimer and Ladd and expands the model to cover multiple transhipment over time and space, facilities existing at the beginning of the planning horizon, and economies of scale in rail transportation resulting from the fixed costs of rail line installation and maintenance.

The method of solution outlined below is divided into two phases. Phase I selects the marketing option for each origin which provides the maximum joint revenue net of variable transportation and processing costs given any locational pattern of subterminals and rail lines, $\overline{TRNVC} \mid \lambda_{mnr}$. A marketing option is defined here as one of many different shipping or marketing patterns over space and time that can be used to move grain from all origins to final destinations. Phase II selects the rail line system and the number and locational pattern of subterminals for which joint net revenue of producers is maximized. Maximum joint net revenue is denoted as $\overline{\Pi}$.

Phase I: optimal marketing options

The flow of grain over time and space is governed by the price at each destination net of handling and transfer costs, subject to the constraint that existing storage facilities of elevators must be fully utilized before any elevator can expand or new facilities be constructed. Phase I suggests a heuristic method to approximate the optimal marketing pattern of shipping grain over time and space from all origins to final destinations.

Two temporal and spatial routing algorithms are used to estimate the optimal flow of grain shipped from origins in month t. The first routing algorithm, used to approximate the optimal flow of grain shipped from origins in month t, takes the marginal costs of storage at elevators as given and independent of volume handled. For month t, the first approximating algorithm sets the marginal cost of storing grain equal to either 1) the marginal operating and maintenance costs of storage; or 2) the marginal operating and maintenance costs of storage plus the marginal costs of expanding storage facilities. The level at which the marginal costs of storage are set depends on the capacity of elevator storage existing at the beginning of month t. Switching rules for changing the level of the marginal costs of storage are presented by equations 4 and 10. Let "optimal routing algorithm: 1st approximation" or ORA $(1,t)|\lambda$ denote the algorithm used as a first approximation of the optimal temporal and spatial routing of grain shipped from origins in month t, given λ_{mnr}.

ORA$(1,t)|\lambda$ provides an optimal routing solution if the data (marginal cost of storing grain) is consistent with the solution (the volume stored). For example, if all elevators have excess storage capacity at the beginning of month t, then the routing of grain will depend, in part, on a marginal cost of storing grain that includes only the marginal operating and maintenance cost of storage. Once the flow of grain has been determined for month t, the volume of grain stored at elevators during month t can be determined. If the volume stored in elevators is less than the storage capacity then the data (marginal operating and maintenance cost of storage) is consistent with the solution; and, the first approximation to the optimal flow of grain is optimal.

The routing solution of ORA$(1,t)|\lambda$ is also optimal if no elevator during month t has excess storage capacity and the marginal costs of storing grain from month t to t + 1, t + 2,...,T are set equal to the marginal operating and maintenance costs of storage plus the marginal costs of expanding storage capacity. All grain received at elevators in month t and shipped out in month t do not incur the marginal costs of expanding storage facilities. Grain that is received in month t and stored beyond month t incur a marginal cost of expanding storage.

In the event that the solution of $ORA(1,t)|\lambda$ suggests that the volume of grain to be stored in, for example, $L2_i$ exceeds the storage capacity of $L2_i$, and the marginal cost of storing grain at elevator $L2_i$ was set equal to only the marginal operating and maintenance costs of storing grain, then, the data of the algorithm are inconsistent with the results. When the data of $ORA(1,t)|\lambda$ are inconsistent with the solution, a second algorithm is used to approximate the optimal routing of grain from all origins to final destinations, in month t, given λ_{mnr}. Denote this second approximating algorithm as "optimal routing algorithm: 2nd approximation", or $ORA(2,t)|\lambda$.

$ORA(2,t)|\lambda$ is used to re-route the flow of grain as determined by $ORA(1,t)|\lambda$ until either all elevators are required to expand storage capacity or until no elevator has to expand storage capacity. Such reroutings are necessary because of the constraint of the model which states that excess storage capacity in any one elevator precludes the expansion of storage capacity in any other elevator.

Following the use of $ORA(2,t)|\lambda$, either all elevators should expand storage capacity; or, no elevator should expand storage capacity for month t. If the results of $ORA(2,t)|\lambda$ suggest that all elevators expand storage capacity, then subtract from the total revenue net of variable costs, the marginal costs of expanding storage facilities. And, because no elevator at the beginning of month t + 1 will have excess storage capacity, in solving $ORA(1,t+1)|\lambda$ for month t + 1, set the marginal cost of storage for all elevators equal to the marginal operating and maintenance costs of storage plus the marginal costs of expanding storage facilities.

When the solution of $ORA(2,t)|\lambda$ suggests that no elevator expand storage capacity, then the marginal cost of storing grain at all elevators for $ORA(1, t+1)|\lambda$ are equal to only the marginal operating and maintenance costs of storing grain. All elevators at the beginning of month t + 1 have excess capacity and, thus, for the first approximation of optimal routings of grain from origins in time t + 1, the marginal expansion costs of storage, S2, are not included.

The methodological framework for solving Phase I using $ORA(1,t)|\lambda$ and $ORA(2,t)|\lambda$ is presented below. Following the methodological framework of Phase I, the methods of solution for $ORA(1,t)|\lambda$ and $ORA(2,t)|\lambda$ are presented.

Methodology: Phase I

A.1. Set month t = 1.

A.2. Set marginal storage costs at elevators equal to marginal operating and maintenance costs of storage. That is:

$$\alpha BS(ø;h_{1s'},.) = BS(ø;h_{1s'},.) \tag{34}$$

and

$$\alpha BS(ø;.i_{1u'},) = BS(ø;.i_{1u'},) \tag{35}$$

for all s' and u'.

A.3. Determine a) the optimal routing of grain shipped from all origins to final destinations; and b) total revenue net of marginal elevator handling and transportation costs, given λ_{mnr}. Use the algorithm specified by $ORA(1,1)|\lambda$ as a first approximation.

A.4. Compute elevator storage capacity existing at the beginning of month 2, given a) the flow of grain over time and space as determined by $ORA(1,1)|\lambda$ and b) the storage capacity of elevators existing at the beginning of month 1. Storage capacity existing at the beginning of month 2 for $L1_h$ and $L2_i$ may be computed as follows:

$$K(h_{s2}.) = K(h_{s1}.) - \sum_{ø} \sum_{s=1}^{2} X(ø;.h_{s,2+1}..) \tag{36}$$

and

$$K(.i_{u2}) = K(.i_{u1}) - \sum_{ø} \sum_{u=1}^{2} X(ø;..i_{u,2+1}.) \tag{37}$$

where, as stated previously, $K(h_{ss'},.)$ denotes the storage capacity at $L1_h$ existing at the beginning of month s'; and $\sum_{ø} \sum_{s=1}^{s'} X(ø;.h_{s,s'+1}..)$ denotes the total volume of grain stored at country elevator $L1_h$ at the beginning of month s'. When s = s', grain is received at $L1_h$ and shipped out in the same month and requires no additional storage.

A.5. If all elevators have excess storage capacity at the beginning of month 2, follow the instructions of A.6. If one or more elevators have deficit storage capacity at the beginning of month 2, follow the instructions of A.7.

Excess storage capacity at the beginning of time s' at Ll_h is defined as $K(h_{ss'},.) > 0$. Deficit storage capacity at Ll_h at the beginning of month s' is defined as $K(h_{ss'},.) \leq 0$.

A.6. If $K(h_{s2}.) > 0$ for all h and $K(.i_{u2}) > 0$ for all i, then the solution of $ORA(1,1)|\lambda$ is optimal. Excess capacity exists at all elevators, the data of the algorithm are consistent with the solution; and the constraint specifying the prerequisite conditions for elevator expansion has not been violated.

Let $\overline{TRNVC}(1,t)|\lambda$ and $\overline{TRNVC}(2,t)|\lambda$ denote the maximum total revenue of producers in time t net of marginal elevator handling costs and marginal transportation costs as approximated by $ORA(1,t)|\lambda$ and $ORA(2,t)|\lambda$ respectively. And, let $\overline{TRNVC}(.t)|\lambda$ denote the maximum total revenue of producers in time t net of marginal elevator handling costs and marginal transportation costs as approximated by the algorithm chosen to solve for the optimal routing of grain during time t.

Thus, if excess capacity exists at all elevators following the use of $ORA(1,t)|\lambda$, then:

(38) $\overline{TRNVC}(.1)|\lambda = \overline{TRNVC}(1,1)|\lambda$

The optimal routing for all origins shipping in month 2 may now be determined by following the steps outlined from B.1 to B.8.

A.7. Use $ORA(2,1)|\lambda$ as a second approximation to the optimal routing of grain shipped from all origins to final destinations during time 1. The algorithm specified by $ORA(2,1)|\lambda$ re-routes the flow of grain as determined by $ORA(1,1)|\lambda$ until all elevators have either excess or deficit storage capacity. The procedures of A.7. satisfy the constraint that excess storage capacity in any elevator precludes another elevator from expanding.

A.8. After solving $ORA(2,1)|\lambda$, compute elevator storage capacity existing at the beginning of month 2. If all elevators have excess storage capacity let:

(39) $\overline{TRNVC}(.1)|\lambda = \overline{TRNVC}(2,1)|\lambda$

and, the optimal routings for all origins shipping in month 2 may now be determined by following the steps outlined from B.1. to B.8.

Or, if all elevators have deficit storage capacity, let:

$$(40) \quad \overline{TRNVC}(.1)|\lambda = \overline{TRNVC}(2,1)|\lambda - S2\left[\sum_h X(.;.h_{s\bar{1}}..) + \sum_i X(.;..i_{u\bar{1}}.) - \sum_h K(h_{s1}.) - \sum_i K(.i_{u1})\right]$$

At the beginning of month 1, the marginal cost of storage was set equal to the marginal operating and maintenance costs of storage and, thus, the marginal costs of expanding storage facilities were not accounted for in $\overline{TRNVC}(1,1)|\lambda$ or $\overline{TRNVC}(2,1)|\lambda$. Equation 40 subtracts from $\overline{TRNVC}(2,1)|\lambda$ the marginal cost of expanding storage capacity in month 1. $X(.;.h_{s\bar{1}}..)$ and $X(.;..i_{u\bar{1}}.)$ as defined previously, denote the total grain stored at $L1_h$ and $L2_i$ through month 1.

Storage capacity existing at the beginning of month 2 must include the storage capacity added to elevators during month 1. Thus, whenever equation 40 is operative, i.e. whenever there is deficit storage capacity at elevators, elevator capacity existing at the beginning of month 2 must be defined as:

$$(41) \quad K(h_{s2}.) = X(.;.h_{s\bar{1}}..)$$

and

$$(42) \quad K(.i_{u2}) = X(.;..i_{u\bar{1}}.)$$

The optimal routing of grain for all origins shipping in month 2 may now be determined by following the steps outlined from B.1. to B.8.

B.1. Set month 2 = t.

B.2. If all elevators at the beginning of month t have excess storage capacity, set:

$$(43) \quad \alpha\, BS(z;h_{ts'}.) = BS(z;h_{ts'}.)$$

and

$$(44) \quad \alpha\, BS(z;.i_{tu'}) = BS(z;.i_{tu'})$$

for all s' and u'.

If all elevators at the beginning of month t have deficit capacity, set:

(45) $\alpha\ BS(\varnothing;h_{ts'}.) = BS(\varnothing;h_{ts'}.) + S2$

and

(46) $\alpha\ BS(\varnothing;.i_{tu'}) = BS(\varnothing;.i_{tu'}) + S2$

for all s' = t + 1, t + 2,...,T; and u' = t + 1, t + 2,...,T. When s' = t and/or u' = t, set the marginal cost of storing grain equal to only the marginal operating and maintenance costs of storing grain.

B.3. Approximate the optimal flow of grain shipped from all origins in month t to final destination by $ORA(1,t)|\lambda$.

B.4. Compute elevator storage capacity existing at the beginning of month t + 1:

(47) $K(h_{s,t+1}.) = K(h_{st}.) - X(.j.h_{st}-..)$

and

(48) $K(.i_{u,t+1}) = K(.i_{ut}) - X(.j..i_{ut}-..)$

B.5. If $K(.i_{u,t+1}) > 0$ and $K(h_{s,t+1}.) > 0$ for all $L2_i$ and $L1_h$, follow the instructions of B.6. If $K(.i_{u,t+1}.) \leq 0$ or $K(h_{s,t+1}.) \leq 0$ for at least one $L2_{i \in \lambda}$ or $L1_{h \in \lambda}$, follow the instructions of B.7.

B.6. Let:

(49) $\overline{TRNVC}(.t)|\lambda = \overline{TRNVC}(1,t)|\lambda$

The optimal routing of grain shipped from all origins in month t + 1 may now be determined by following the steps outlined in C.1.

B.7. Use $ORA(2,t)|\lambda$ as a second approximation to the optimal routing of grain shipped from all origins during month t.

B.8. Compute elevator storage capacity existing at the beginning of month t + 1, based on the solution of $ORA(2,t)|\lambda$. If all elevators have excess storage capacity let:

(50) $\overline{TRNVC}(.t)|\lambda = \overline{TRNVC}(2,t)|\lambda$; and, the optimal routing of grain shipped from all origins in month t + 1 may now be determined by following the instructions of C.1.

Or, if all elevators have deficit storage capacity, let:

$$(51) \quad \overline{TRNVC}(.t) \mid \lambda = \overline{TRNVC}(2,t) \mid \lambda - S2 \left[\sum_h X(.;.h_{s\bar{t}}..) + \sum_{i \in \lambda} X(.;..i_{u\bar{t}}.) - \sum_h K(h_{st}.) - \sum_i K(.i_{nt}) \right];$$

define elevator storage capacity existing at the beginning of month t + 1 as:

$$(52) \quad K(h_{s,t+1}.) = X(.;.h_{s\bar{t}}..)$$

$$(53) \quad K(.i_{u,t+1}) = X(.;..i_{u\bar{t}}.);$$

and, the optimal routing of grain shipped from all origins in month t + 1 may now be determined by following the instructions of C.1.

C.1. The optimal routing of grain shipped from all origins in month j for a given locational pattern of subterminals and rail lines may be approximated for months j = 2,3,...,T by setting month j = t and repeating the steps outlined from B.2. to B.8.

D.1. Once the optimal route of grain shipments from all origins, and the maximum total revenue net of variable costs have been computed for each time t, the last step of Phase I is to determine the joint revenue of producers net of variable costs over all time periods given λ_{mnr}. Denote maximum joint revenue of producers net of variable costs, given λ , as $\overline{TRNVC} \mid \lambda_{mnr}$ and compute as follows:

$$(54) \quad \overline{TRNVC} \mid \lambda_{mnr} = \sum_t \overline{TRNVC}(.t) \mid \lambda$$

Optimal routing algorithm: 1st approximation

ORA(1,t) | λ determines the optimal marketing options for all origins shipping in time t, given constant marginal handling costs and λ_{mnr}. For each locational network of elevators and rail lines, λ_{mnr}, there are many different possible shipping or marketing patterns over space and time for each origin. During one year with T marketing periods there are

$$(55) \quad J \sum_{t=1}^{T} t(H+n) + (t^2 - \sum_{t'=1}^{t} (t'-1)) Hn$$

different marketing options for each origin. A locational pattern with thirteen destinations, seven subterminals, eighty-seven country elevators, and twelve time periods offers 2,977,104 marketing options for origin g.

One method to find the maximum joint revenue net of variable costs given λ_{mnr} would be to compute and compare all possible marketing combinations for all origins and select that set which achieves the objective. If there were 416 origins, with each origin selecting from 2,977,104 marketing options, the number of marketing combinations given λ_{mnr} exceeds one billion.

Another procedure, and the one used in this study, to find the optimal routings, given λ_{mnr}, for each origin in time t decomposes the marketing system into parts and solves the parts sequentially. This method reduces the number of marketing options requiring comparison for origin g, for example, from 2,977,104 to 143,962 when J = 13, I = 7, H = 87, and T = 12. The number of comparisons required to select the optimal routing for origin g is further reduced if information that was obtained when evaluating other locational patterns is also used.

ORA(1,t) $|\lambda$ assumes that the flow of commodities over time and space is governed by the price of each final destination net of marginal elevator handling and transportation costs. Each source $L2_i$, $L1_h$, or g ships to that location offering the highest net price regardless of the quantity shipped. The highest net price, for example, at subterminal $L2_i$ in time t is determined by comparing all possible routings over time and space; and selecting that combination of storage, transportation, and destination for which the net price is highest. Net price at $L2_i$ in time t is determined by subtracting from the price at destination L_j in time v: 1) the marginal transportation costs from $L2_i$ to L_j in time v; 2) the marginal load out costs at $L2_i$ in time v; 3) the marginal cost of storing grain at $L2_i$ from time t to time v; and 4) the marginal cost of receiving grain at $L2_i$ in time t.

Regardless of the quantity received in time t by $L2_i$ there will only be one marketing option over time and space which provides a net price at least as high as any other option. Any source comparing $L2_i$ with other destinations needs only to compare the best net price at $L2_i$ rather than all possible transhipment alternatives through $L2_i$. This suggests that the marketing system may be decomposed into various segments or stages of transhipment and routes determined by sequentially selecting the optimal marketing option for each stage.

In short, origin g in time t selects an optimal marketing pattern based on the routing selections of plants type 1 and 2. Plants type 1 select an optimal marketing pattern based on selections of plant type 2 and prices at the final destination. Plants type 2 base their selection on prices at the final destination.

A first approximation to the optimal marketing pattern for origin g in time t may, thus, be selected sequentially by the following steps of $ORA(1,t)|\lambda$:

1. For each time period that $L2_i$ receives commodity ø, select the combination of storage, transportation, and destination L_j for which the net price will be at least as high as any other combination. All of commodity ø received during time t will be stored for the number of periods and shipped to that destination selected.
2. Specify for all origins and country elevators a set of destinations which include a) L_j where $j = 1,2,\ldots,J$; and b) all plants of type 2. Each L_j and $L2_i$ offer a unique price at time t. The price at L_j time t is predetermined. The price at $L2_i$ time t is net of storage, handling, and transportation cost.
3. For each time period that $L1_h$ receives commodity ø, determine the combination of storage, transportation, and destination which provides a net price at least as high as any other combination. Commodities received during time 1 will be channeled through one of $T(I + J)$ marketing option.
4. Specify for all origins a set of destinations which include plants of type 2 and plants of type 1. Each $L2_i$, and $L1_h$ offer a unique price at time t for commodity ø.
5. For each origin g that ships commodity ø in time t, select the combination of storage, transportation, and destinations which provides a net price at least as high as any other combination. Commodity ø shipped during time t will be channeled through one of $(H + I)$ marketing options. Net price at origin g in time t when shipping, for example, grain from origin g to a country elevator located at $L1_h$ is equal to the maximum net price at $L1_h$ in time t minus the marginal

transportation cost from g to $L1_h$.

6. For each origin g in month t determine the maximum revenue net of marginal elevator handling and transportation costs. Maximum net price at origin g in month t multipled by the volume of grain shipped from origin g in month t equals maximum revenue net variable costs for origin g in month t. Adding together the maximum revenue net variable costs for all origins in month t provides $\overline{TRNVC}(1,t) \mid \lambda$.

The algorithm used to estimate $\overline{TRNVC}(1,t) \mid \lambda$ may be alternatively expressed as follows: Let $\pi(\mathfrak{s};...j_v)$ denote the predetermined price of commodity $\mathfrak{s}$ at destination L_j in time v; j = 1,2,...,J. The net price at processing plant $L2_i$, for commodities received in time u when they are stored to time v and shipped to destination L_j in time v, can be computed as:

$$(56)\qquad \pi(\mathfrak{s};..i_{uv}j_v) = \pi(\mathfrak{s};...j_v) - \beta R(\mathfrak{s};.i_{u.}) - \alpha\beta S(\mathfrak{s};.i_{uv}) - \beta L(\mathfrak{s};.i_{.v}) - C(\mathfrak{s};..i_{.v}j_v)$$

The maximum net price of commodity $\mathfrak{s}$ at $L2_i$ time u can be determined by selecting the storage and destination combination which provides a net price at least as high as any other combination. This may be expressed as:

$$(57)\qquad \pi(\mathfrak{s};..i_{u\bar{v}}\,\bar{j}_{\bar{v}}) = \max_j \max_v \pi(\mathfrak{s};..i_{uv}j_v)$$

Define a set of destinations, j1, for shipments from country elevators, which include original destinations Lj, j = 1,2,...,J; and plants type 2, $L2_i$, $i \in \lambda_{mnr}$. Thus, j1 = 1,2,...J, J + 1, J + 2,...,J + I where j1 = 1,2,...,J denote terminal markets, L_j; and j1 = J + 1, J + 2,...J + I denote subterminals, $L2_i$.

Let $\pi(\mathfrak{s};...j1_v)$ denote the maximum price of commodity $\mathfrak{s}$ offered at destination j1 time v. The maximum net prices for j1 = J + 1, J + 2,..., J + I equal $\pi(\mathfrak{s};..i_{u\bar{v}}\,\bar{j}_{\bar{v}})$; u = v.

The net price, therefore, at plant $L1_h$, when commodities $\mathfrak{s}$ received in time s are stored to time v and shipped to destination j1 in time v, may be computed:

(58) $$\pi(\mathfrak{s};.h_{sv}.j1_{v}) = \pi(\mathfrak{s};...j1_{v}) - \beta R(\mathfrak{s};h_{s.}.)$$

$$- \alpha\beta S(\mathfrak{s};h_{sv}.) - \beta L(\mathfrak{s};h_{.v}.) - C(\mathfrak{s};.h_{.v}.j_{v})$$

when j1 = 1,2,...,J; and

(59) $$\pi(\mathfrak{s};.h_{sv}.j1_{v}) = \pi(\mathfrak{s};...j1_{v}) = \beta R(\mathfrak{s};h_{s.}.)$$

$$- \alpha\beta S(\mathfrak{s};h_{sv}.) - \beta L(\mathfrak{s};h_{.v}.) - C(\mathfrak{s}.h_{.v}i_{v.}.)$$

when j1 = J + 1, J +2,..., J + I.

The maximum net price of commodity $\mathfrak{s}$ at $L1_h$ in time s, when selecting the storage and destination combination which provides a net price at least as high as any other combination, may be expressed as:

(60) $$\pi(\mathfrak{s};.h_{s\bar{v}}.\overline{j1}_{\bar{v}}) = \max_{j1}\max_{v} \pi(\mathfrak{s};.h_{sv}.j1_{v})$$

Define a set of destinations, j2, for shipments from origins which include: 1) country elevators $L1_h$, h = 1,2,...,H; and 2) subterminals $L2_{i \epsilon \lambda}$ i = 1,2,...,I. Thus, j2 = 1,2,...,H, H + 1, H + 2,...,H + I where j2 = 1,2,...,H denote all country elevators; and j2 = H + 1,...,H + I denote all subterminals in locational option λ_{mnr}.

Let $\pi(\mathfrak{s};...j2_{v})$ denote the maximum price of commodity $\mathfrak{s}$ offered at destination j2 time v. The maximum net prices for j2 = 1,2,...,H equal $\pi(\mathfrak{s};.h_{s\bar{v}}.\bar{j}_{\bar{v}})$ when h = 1,2,...,H; and j2 = H + 1, H + 2,..., H + I equal $\pi(\mathfrak{s};..i_{u\bar{v}}\bar{j}_{\bar{v}})$ when i = 1,2,...,I.

The net price at origin g when shipping commodity $\mathfrak{s}$ in time v directly to destination j2, may now be computed as:

(61) $$\pi(\mathfrak{s};g_{v}..j2_{v}) = \pi(\mathfrak{s};...j2_{v}) - C(\mathfrak{s};g_{v}h_{v.}..)$$

when j2 = 1,2,...,H; and

(62) $$\pi(\mathfrak{s};g_{v}..j2_{v}) = \pi(\mathfrak{s};...j2_{v}) - C(\mathfrak{s};g_{v}.i_{v.}.)$$

when j2 = H + 1, H + 2,..., H + I.

The maximum net price at origin g time v, when selecting marketing option over time and space which offers a net price at least as high as any other combination, may be expressed as:

$$(63) \qquad \pi(z;g_v..\bar{j}2_v) = \max_{j2} \pi(z;g_v..j2_v)$$

Once the optimal marketing pattern has been approximated over time and space for the grain shipped from each origin in time t, the total revenue and variable costs forthcoming from that pattern can be computed for time t. The final step of $ORA(1,t) \mid \lambda$ is to compute total revenue of all producers in time t net of variable costs, $\overline{TRNVC}(1,t) \mid \lambda$. $\overline{TRNVC}(1,t) \mid \lambda$ as estimated by $ORA(1,t) \mid \lambda$ is computed as follows:

$$(64) \qquad \overline{TRNVC}(1,t) \mid \lambda = \sum_z \sum_g X(z;g_t...) \; \pi(z;g_t..\bar{j}2_t)$$

<u>Optimal routing algorithm: 2nd approximation</u>

Using $ORA(1,t) \mid \lambda$ as a first approximation of optimal marketing routes may result in a solution that is inconsistent with the constraint that excess storage capacity in any elevator precludes the expansion of storage capacity in another elevator. $ORA(2,t) \mid \lambda$, as a second approximation to the optimal marketing routes for all origins shipping in time t, takes into account the prerequisite conditions for elevator expansion. Imposing this expansion constraint on the plant-location model is similar to a problem, as specified by Ladd, containing "two-sided quantity restrictions". That is, the quantity available at each origin and maximum quantity required at each destination are a known constant.

The general method of solution for problems containing "two-sided quantity restrictions" as outlined by Ladd may be used to solve $ORA(2,t) \mid \lambda$. $ORA(1,t) \mid \lambda$ may be used as a first approximation of shipments from origin to elevators. The solution of $ORA(1,t) \mid \lambda$ can then be compared with capacity restrictions of elevators. In the event that Ll_h has excess storage capacity and Ll_k has deficit capacity, grain may be re-routed 1) spatially from Ll_h to Ll_k until both Ll_h and Ll_k have either excess or deficit storage capacity; 2) temporally by transhipping grain received from some origins to final destinations during the same month the grain is received. That is, grain shipped from some origins to Ll_k in time s may be re-routed over time from $X(z;.k_{ss'}..)$, $s < s'$ to $X(z;.k_{ss}..)$.

Such temporal re-routing would continue until Ll_k had excess capacity. Or 3) a combination of 1 and 2.

With more than two elevators, off-setting re-routings are also possible. If Ll_k has deficit storage capacity, $X(s;4_t k_{ts},..)$ may, for example, be re-routed from Ll_k to either Ll_1 or Ll_2. Or, grain may be re-routed from Ll_k to Ll_1, and to prevent the re-routing from exceeding capacity at Ll_1, $X(s;5_t l_{ts},..)$ may be re-routed from Ll_1 to Ll_2. The many possible off-setting re-routing combinations and combinations of re-routing over time and space suggests the need for a set of simplified heuristic re-routing rules.

The following three steps of $ORA(2,t)|\lambda$ may be used to approximate the routing of grain shipped from origins in time t, given λ_{mnr} and the prerequisite conditions for expansion. Step 4 estimates $\overline{TRNVC}(2,t)\ |\lambda$; that is, total revenue of all producers in time t net of variable costs, given λ.

Step 1: Let $ORA(1,t)|\lambda$ be used as a first approximation of the optimal routings of grain from origins to elevators and final destinations in time t.

Step 2. Define the best re-routing of grain from one elevator to another elevator as the spatial re-routing alternative that minimizes the change in marginal transportation costs resulting from the re-routing of grain. Denote the minimum change in marginal transportation costs from re-routing grain from country elevator Ll_k to another country elevator in time t, given λ as:

$\Delta TC(k_1.t)|\lambda$. $\Delta TC(k_1.t)|\lambda$ may be computed as follows:

$$(65)\qquad \Delta TC(k_1.t)|\lambda = \min_{h\in\lambda}\ \min_{g}\ \sum_{s} X(s;g_t...)\left[C(s;g_t h_t..) - C(s;g_t k_t..)\right]$$

where $Ll_k \neq Ll_h$.

Denote the minimum change in marginal transportation costs from re-routing grain from country elevator Ll_k to a subterminal in time t, given as:

$\Delta TC(k_2.t)|\ \lambda$ and compute as follows:

$$(66)\qquad \Delta TC(k_2.t)/ = \min_{i\in\lambda}\ \min_{g}\ \sum_{s} X(s;g_t...)\left[C(s;g_t.i_t..) - C(s;g_t k_t..)\right]$$

where $L1_k \neq L2_i$.

Define the best re-routing of grain from $L1_k$ to another elevator in time t given λ as:

(67) $$\Delta TC(k\ .t) | \lambda = \min_w \Delta TC(k_w.t) | \lambda .$$

The best re-routing of grain from subterminals to other elevators is defined similar to the best re-routing of grain from country elevator. Denote the minimum change in marginal transportation costs from re-routing grain from subterminal $L2_{k'}$ to a country elevator in time t, given λ , as $TC(.k'_1) | \lambda$ and compute as follows:

(68) $$\Delta TC(.k'_1) | \lambda =$$

$$\min_{h \in \lambda} \min_g \sum_{s} X(s;g_t...) \left[C(s;g_t h_{t.}..) - C(s;g_t.k'_{t.}.) \right]$$

where $L1_h \neq L2_{k'}$..

Denote the minimum change in marginal transportation costs from re-routing grain from subterminal $L2_{k'}$ to a subterminal in time t, given λ, as $\Delta TC(.k'_2) | \lambda$ and compute as follows:

(69) $$\Delta TC(.k'_2) / \lambda =$$

$$\min_{i \in \lambda} \min_g \sum_{s} X(s;g_t...) \left[C(s;g_t.i_{t.}.) - C(s;g_t.k'_{t.}.) \right]$$

where $L2_i \neq L2_{k'}$.

Define the best re-routing of grain from subterminal k located at $L1_k$ to another elevator in time t given λ as:

(70) $$\Delta TC(.k'_{.}t) | \lambda = \min_w \Delta TC(.k'_w t) | \lambda .$$

Step 3: Re-route grain, based on the re-routing definitions presented in equations 67 and 70, until all elevators have either excess or deficit storage capacity. One re-routing, however, of the shipments of origin g from elevator k to elevator h may not be sufficient to provide the required excess or deficit storage capacity for elevator k or h. Thus, re-route grain first, based on the best re-routing options of equations 67 and 70. If additional re-routings are required, re-route grain based on the next best re-routing options. Continue in this manner until all elevators have either excess or deficit storage capacity.

Let $\Delta TTC(h.t) | \lambda$ denote the total change in marginal transportation costs from re-routing grain from country elevator h in time t, given λ. In the event that only one re-routing from country elevator h is necessary to satisfy the condition that all country elevators have either excess or deficit capacity, then $\Delta TTC(h.t) | \lambda = \Delta TC(\dot{h}.t) | \lambda$. If more than one re-routing of grain from country elevator h is required then $\Delta TTC(h.t) | \lambda$ includes not only the change in transportation costs resulting from the first re-routing, but also all other changes in transportation costs resulting from re-routing grain from country elevator h.

Step 4: Once the optimal marketing pattern has been approximated over time and space for the grain shipped from each origin in time t, and such routings are consistent with the constraint that no elevator can expand storage capacity if excess storage capacity exists at any other elevator, then $\overline{TRNVC}(2,t) | \lambda$ can be computed. $\overline{TRNVC}(2,t) | \lambda$ denotes the maximum total revenue of all producers in time t net of variable costs as approximated by $ORA(2,t) | \lambda$.

$\overline{TRNVC}(2,t) | \lambda$ is computed as follows:

$$(71) \quad \overline{TRNVC}(2,t) | \lambda = \overline{TRNVC}(1,t) | \lambda - \sum_{h \in \lambda} \Delta TTC(h.t) | \lambda - \sum_{i \in \lambda} \Delta TTC(.it) | \lambda .$$

<u>Phase II: optimal number and locational pattern</u>

For any given number of subterminals and branch rail lines there are many possible locational combinations. Thirty plant sites, for example, taken nine at a time provides 14,307,150 combinations. And, for each locational pattern there will be one optimal marketing option and $\overline{TRNVC}$ as defined in Phase I. Fortunately, in the selected area all country elevators were in existence at the beginning of the planning horizon; and only four rail line network patterns were considered as viable alternatives.

The objective of Phase II is to select the number and locational pattern of subterminals, and rail line system for which π is maximized. Total net revenue, Π, may be computed for each λ_{mnr} as follows:

$$(72) \quad \Pi / \lambda_{mnr} = \overline{TRNVC} / \lambda_{mnr} - \sum_{h} \alpha(h.) - \sum_{i \in \lambda} \alpha(.i) - \gamma_r .$$

Maximum joint net revenue, $\bar{\Pi}$, is found by systematically comparing Π for each combination of λ_{mnr} and selecting that combination for which Π is maximum. This may be expressed as:

$$(73) \quad \bar{\Pi} = \max_{r} \max_{n} \max_{m} \Pi \mid \lambda_{mnr} .$$

The model as stated thus far, assumes prices at final destinations are known with certainty. As a result, the computer solution calls for shipping very large quantities of grain in a given month to the market with the highest net price. In many cases, the amount shipped is in excess of the quantity of grain that the market could absorb at the stated price. The best way to solve this problem is to construct monthly demand functions at each market. However, this was not possible because of data limitations. An alternative method of solving this problem was to specify alternative monthly shipping patterns which specified predetermined percentage of total receipts to be shipped for each month. A second model was developed to determine the spatial flow of grain from elevators and subterminals to final markets to maximize joint net revenue to the system given the alternative monthly shipping pattern.

Model II

The annual volume of grain at elevators, and alternative monthly shipping patterns are predetermined. The locational pattern of elevators and rail lines are also determined exogenously.

A monthly shipping pattern specifies the amount of grain shipped each month from elevators to terminal markets. One monthly shipping pattern, for example, may specify an equal amount of grain shipped each month. Another monthly shipping pattern may specify a monthly distribution designed to take advantage of the high demand prices at terminal markets existing at the end of the marketing year.

Demand prices, historically, are higher in the summer than during the fall harvest season. The transportation system can expand capacity to meet peak demands. Such expansion, however, is costly and must be balanced against the advantages of shipping large volumes of grain during periods when demand prices are high.

Let:

$\gamma'(w)$ = annual cost of expanding transportation capacity to handle the peak demands of the wth monthly shipping pattern.

$\emptyset(s;t,w,)$ = percent of 1980 volume of commodity s shipped in period t, given the wth monthly shipping pattern.

and

$\Pi'/_w$ = Total net revenue of producers given the wth monthly shipping pattern.

$$(74)\quad \Pi'/_w = \sum_{s}\sum_{t} \emptyset(s;t;w)\left\{\sum_{i}\sum_{u} X(s;..i_{.u}.)\left[\pi(s;...j_t) - \alpha\beta(s;.i_{t,t+1}) - \beta(s;.i_{t.}) - \beta(s;.i_{.t}) - C(s;..i_{.t}j_t)\right]\right\}$$

$$+ \sum_{s}\sum_{t} \emptyset(s;t,w)\left\{\sum_{h}\sum_{s} X(s.h_{.s}.j_s)\left[\pi(s;...j_t) - \alpha\beta(s;h_{t,t+1}.) - \beta(s;h_{t.}.)\right.\right.$$

$$- \beta(s;h._t.)$$

$$\left.\left. - C(s;.h_{.t}.j_t)\right]\right\} - \gamma'_w$$

Terms within the first set of { } represent total revenue net of 1) marginal transportation costs from subterminals to final destinations and 2) marginal receiving, storage and load out costs of subterminal, given the wth monthly shipping pattern. Terms within the second set of { } represent total revenue net of 1) marginal transportation costs from country elevators to final destinations and 2) marginal receiving, storage, and load out costs of country elevators, given the wth monthly shipping pattern. All symbols except $\emptyset(s;t,w)$ and γ'_w were defined for Model I. Variables $\sum_i \sum_u X(s;..i_{.u}.)$ and $\sum_h \sum_s X(s;.h_{.s}.\bar{j}_s)$ for Model II, however, are exogenous.

The method of solution is similar to Model I. Each subterminal and elevator shipping grain to terminal market j in month t, selects that destination for which net price is highest. One difference between Model I and Model II is that in Model I, an elevator selects the best location and time to ship grain. In Model II an elevator selects only the best location to ship grain because the monthly shipping pattern is predetermined as specified by $\emptyset(s;t,w)$.

Appendix B

Comparison of Estimated On-Farm and Elevator Storage and Drying Costs

The purpose of this analysis is to compare the annual total costs and per bushel costs of additions to elevator drying and storage systems and of new storage and drying systems on the farm.

Six on-farm systems for drying and storage are considered. They are 25,000 bushels storage with a 180 bushel per hour dryer, 50,000 bushels storage with a 180 bushel per hour dryer, 50,000 bushels storage with a 360 bushel per hour dryer, 75,000 bushels storage with a 180 bushel per hour dryer, 75,000 bushels storage with a 360 bushel per hour dryer, and 75,000 bushels storage with a 550 bushel per hour dryer.

The average farmer of this study is assumed to harvest corn with a six-row combine having a harvesting capacity of 600 bushels per hour. The farmer is assumed to harvest 12 hours per day and dry 20 hours per day. Corn is harvested at an average of 25 percent moisture and is dried to 13 percent for on-farm storage. The operating conditions of this study are assumed to be typical 1980 farm operations.

Two sizes of elevator additions are considered -- 100,000 bushels storage with no additional dryer capacity and 250,000 bushels capacity with an additional 750 bushel per hour dryer. Elevators with and without direct railroad access are also compared.

It is assumed the elevator will maintain a corn-soybean receipt ratio of approximately 70 percent-30 percent. Elevators without direct railroad access will be filled once a year. Elevators with direct railroad access will be filled one and one-half times a year. The first fill will be available for hedging, service, drying, and handling margin revenues, but the one-half fill will be available for handling and drying revenues only. We assume an average of 10 points moisture removal on corn receipts at all elevator models.

Cost and revenue figures for the elevator additions are based upon the data in Appendix H.

Dr. Robert N. Wisner assisted with this analysis.

Equipment

Continuous-flow dryers are used in all on-farm systems. The rated capacity is for 10 points moisture removal from 25 to 15 percent moisture. This rated capacity drops 20 percent when grain is dried an additional 2 points from 15 to 13 percent moisture. All wet corn holding bins are built at ground level. Bucket elevators are used in the five larger on-farm systems, but a storage capacity of 25,000 bushels would not justify use of this equipment. Storage bins of on-farm systems are corrugated metal and are complete with foundations, aeration equipment, and handling equipment. An average price discount for on-farm drying and storage equipment is 8 percent. This discount would vary according to the time of the year in which the purchase was made.

Equipment used in elevator additions includes corrugated metal storage bins, aeration equipment, and conveyors. Present drying capacity of the elevator is considered to be adequate for the 100,000 bushel addition, but a 750 bushel per hour continuous-flow dryer and an additional leg are assumed to be needed for the 250,000 bushel addition.

Elevator revenues

Handling margins - A 3 cent per bushel handling margin on corn is assumed for elevators with direct rail access and elevators on abandoned rail lines. For elevators on abandoned rail lines trucking costs of 3 cents per bushel are assumed to reduce the handling margin on corn to zero.

A 4 cent per bushel handling margin on soybeans is assumed for all elevator models. Trucking costs of 3 cents per bushel on all soybeans stored will reduce the margin to 1 cent per bushel for elevators without direct rail access. For elevators on railroads, 25 percent of the soybeans will be shipped by truck to local processors at a cost of 3 cents per bushel, leaving a handling margin of 1 cent per bushel. The remainder will be shipped by rail and will realize the full 4 cent per bushel handling margin.

Drying revenue - The elevator charges for drying grain are assumed to be 5 cents for the first 5 points of moisture removed and 0.5 cent for each additional point removed.

Storage income - Income received from additional storage of grain is estimated by computing the per bushel revenue from storage and applying this per bushel cost to the increased storage capacity.

Hedging revenue - Approximately 30 percent of the corn receipts are assumed to be available for hedging. A net gain of 9.1 cents per bushel is expected utilizing the following data:

Basis improvement (5 year average)		16.0¢
Less:	interest costs at 8 percent annual rate for 7 months of storage on $1.05 corn)	4.9¢
	shrinkage	1.5¢
	insurance	.5¢
Net gain per bushel		9.1¢

Approximately 40 percent of the soybean receipts are assumed to be available for hedging during the harvest season. Lifting of soybean hedges and sales of soybeans to local processors will be made in equal amounts each month throughout the year. Harvest-time hedges will be held for a maximum of 3 months. A portion of the soybeans purchased from farmers during the spring will be hedged and stored into the summer, but storage costs on these soybeans will exceed hedging revenues.

Table 39 shows the time patterns of soybean purchases, monthly carrying costs, hedging revenues, and profits.

<u>Elevator costs</u>

Annual depreciation and interest - The straight line method of depreciation is used. Metal bins at the elevator are assumed to have a useful life of 20 years. Aeration and handling equipment is assumed to have a useful life of 10 years. No salvage value is assumed on any of the equipment. An interest rate of 10 percent is assumed on the equipment.

Actual cost for annual depreciation and interest was found by multiplying the total investment cost times a capital recovery factor which converts the investment cost to an annual cost.

Drying costs - Variable drying costs at the elevator are assumed to be five-sixths of the farm rate of 3.5 cents which would be 2.9 cents per bushel at the elevator. The factor of five-sixths is based on an average of 10 points of moisture removed at the elevator compared to 12 points moisture removed for on-farm storage.

Table 39.

Budgeted Country Elevator Soybean Hedging Operations.

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	
Farmer sales pattern (Percent of beans sold monthly)		40		0	0	8.6	8.6	25.6	8.6	8.6	0	0	
Gross hedging returns	0	0	5¢	9.5¢	11.5¢	0	0	0	0	4¢	4¢	2¢	
Carrying cost per bushel ($3 per bushel, 8 percent interest)	0	0	2¢	4¢	6¢	0	0	0	0	4¢	6¢	4¢	
Net returns per bushel	0	0	3¢	5.5¢	5.5¢	0	0	0	0	0	-2¢	-2¢	
Volume sold by elevator (100,000 bushel addition)		2,458 bushels per month											
Net hedging return	0	0	$74	$135	$135	0	0	0	0	0	-$49	-$49	
Total net hedging returns from soybeans													$246
Volume sold by elevator (250,000 bushel addition)		6,145 bushels per month											
Net hedging returns	0	0	$184	$338	$338	0	0	0	0	0	$-123	$-123	
Total net hedging returns from soybeans													$614

Labor - Additional labor cost for operation of the 100,000 bushel addition was estimated to be $500. Labor cost for the operation of the 250,000 bushel addition was estimated to be $1,250. These figures are based on estimates made in Appendix H.

For elevators with railroads which have a turnover rate of 1.5, the additional labor cost for the one-half additional volume is estimated by finding the per bushel cost for one turnover of the additional volume and applying that per bushel cost to the one-half turnover.

Utilities - The additional cost of utilities was estimated to be 10 percent of the present utility cost of the elevator studied for the 100,000 bushel addition and 25 percent of the present cost for the 250,000 bushel addition. For elevators having a turnover rate of 1.5, the cost of a single turnover was multiplied by 1.5.

Property taxes - Property taxes were computed at the rate of 80 mills on 27 percent of the initial construction cost.

Insurance - Insurance on inventory and equipment is computed at the rate of 18 mills per dollar of original investment.

Repairs - The repair cost for the addition was estimated by finding the average cost per bushel for repairs of the elevator studied in Appendix H and applying that cost to the addition.

<u>On-farm variable costs</u>

Drying - On-farm drying costs are calculated at the rate of 3.5 cents per bushel for 12 percent moisture removal. This cost includes labor and utilities associated with drying.

Handling - Handling costs for moving grain into and out of the on-farm system are 1 cent per bushel. This is based on a labor charge of $3 per hour.

Shrinkage and quality deterioration - A charge of 2.1 cents per bushel is made for additional shrinkage and quality deterioration due to drying from 15.5 to 14 percent moisture for on-farm storage.

<u>On-farm fixed costs</u>

Property taxes - Property taxes are calculated at the rate of 80 mills on 27 percent of the initial construction cost.

Insurance - Insurance on inventory and equipment is computed at the rate of 18 mills per dollar of original investment.

Repairs - Repair cost was estimated to be 2 percent of the original cost

Annual depreciation and interest - The straight line method of depreciation is used. All equipment in on-farm systems is estimated to have a useful life of 12 years. Salvage value is estimated to be 5 percent of the initial cost. An interest rate of 7 percent is used.

Annual depreciation and interest cost is computed as an annual equivalent cost by multiplying the initial cost times a factor to convert the investment cost to an annual cost at 7 percent interest. The salvage value is multiplied by a factor which gives an annual value. The difference of the two numbers is interpreted as annual depreciation and interest cost.

Summary and conclusion

Annual per bushel costs for the on-farm grain storage and drying systems considered in this study range from a low of 18 cents to a high of 21.18 cents. These costs vary directly with dryer capacity and inversely with storage capacity.

Annual costs per bushel for additions to elevators without direct railroad access were estimated to be 11.26 cents for a 100,000 bushel addition and 12.24 cents for a 250,000 bushel addition. Resulting profits were 1.1 cents and 0.12 cent respectively. Costs per bushel for additions to elevators on operating rail lines were the same as for elevators without direct rail access, but profits were higher, 3.88 cents and 2.9 cents respectively, due to decreased transportation costs. Assuming that the elevators on operating rail lines were able to handle one and one-half times their sales volume per year due to their direct access to rail transportation facilities, costs per bushel would drop to 8.47 cents for the 100,000 bushel addition and 9.12 cents for the 250,000 bushel addition. Profits would be 4.42 cents and 3.76 cents respectively. In the situations examined in this study, profits per bushel would be lower for the 250,000 bushel addition because of higher equipment costs incurred with additional dryer capacity. The 100,000 bushel addition was assumed to utilize existing dryer capacity, so that additional drying facilities were not required.

The results of this study indicate that, under normal conditions, there is a cost advantage from building additional storage at the country elevator rather than on the farm. Railroad facilities are almost essential if the elevator is to make a significant profit with the new facilities. It may be possible for an elevator on an abandoned rail line to build additional storage and make a profit on the extra volume if the cost of the addition is kept at a minimum or merchandising margins are larger than those assumed in this study. If the additional volume is too large for the elevator's present drying and handling facilities, the cost of adding this equipment would make additional storage of this size unprofitable. The addition must be small enough to be compatible with the present drying and handling facilities.

The costs of all sizes of farm systems considered were above the typical elevator charge for drying and storage. This would again indicate that under normal conditions there is a cost advantage in adding drying and storage facilities at the elevator. There are other variables which in some cases offset these cost disadvantages. The farmer may hold unit costs down by offsetting initial construction costs with longer harvesting and drying periods. This could be accomplished by purchasing equipment with less drying and receiving capacity and then allowing for a longer harvesting and drying period. Compared to the country elevator, the farmer has fewer opportunities for reducing costs by handling more than one turnover of volume through his system in one year. In fact, on-farm systems may sit idle much of the year.

It must be emphasized that all estimates and assumptions in this study are based upon average conditions. Results may be altered depending upon the operating conditions. For example, actual dryer capacities may vary depending on weather conditions. Also, earnings such as hedging revenue may vary according to the experience and management ability of the operator.

There are additional factors on both sides of this analysis which may affect the farmer's decision on how to dry and store his grain. These factors may have an effect on the cost and revenue figures of the systems, depending upon conditions, but are in themselves so variable it would not be practical to estimate their effect on income in a general situation.

One factor not considered is the possibility of the elevator handling more than one or one and one-half turnovers of volume per year. During a year it may be possible for an elevator to handle several times its storage capacity. This would tend to decrease unit costs as volume handled increased.

A second factor facing the farmer is the amount of time spent waiting in receiving lines at country elevators. Time spent waiting in line, if figured at a per bushel cost and added to the elevator charges, could make on-farm handling systems more attractive to the high volume producer.

Another factor of interest to the farmer is flexibility of operation. If a farmer has on-farm grain handling facilities, he has a greater range of options for marketing his grain. If the grain is stored at an elevator, the farmer may not be able to take advantage of a higher price offered by another elevator. The cost of removing the grain and hauling it to the other elevator would probably negate any price advantage.

Table 40.

Estimated On-Farm Drying and Storage Equipment and Construction Costs for Six Sizes of Drying and Storage Systems 1972.

Item	System 1*	System 2*	System 3*	System 4*	System 5*	System 6*
Dryer, installed	$ 9,392	$ 9,392	$13,082	$ 9,392	$13,082	$15,050
Storage bin(s)	8,500	16,500	16,500	24,750	24,750	24,750
Holding bin	1,700	3,360	3,360	5,280	5,280	5,280
Swingaway unloading auger	800	------	------	------	------	------
Bucket elevator	------	7,000	7,000	7,000	7,000	7,000
Pit	------	1,200	1,200	1,400	1,400	1,400
Cross augers	------	500	500	1,000	1,000	1,000
Wiring	1,200	1,400	1,400	1,600	1,600	1,600
Subtotal	$21,592	$39,352	$43,042	$50,422	$54,112	$56,080
Less 8 percent equipment discount	1,428	2,482	2,770	3,154	3,442	3,598
	$20,164	$36,870	$40,272	$47,268	$50,670	$52,482
Plus 3 percent sales tax	605	1,106	1,208	1,418	1,520	1,574
Total	$20,679	$37,976	$41,480	$48,686	$52,190	$54,056

*System 1 - 25,000 bushels storage, 180 bushel per hour dryer.
System 2 - 50,000 bushels storage, 180 bushel per hour dryer.
System 3 - 50,000 bushels storage, 360 bushel per hour dryer.
System 4 - 75,000 bushels storage, 180 bushel per hour dryer.
System 5 - 75,000 bushels storage, 360 bushel per hour dryer.
System 6 - 75,000 bushels storage, 550 bushel per hour dryer.

Table 41.

Estimated Elevator Drying and Storage Construction Costs for Two Sizes of Drying and Storage Systems 1972.

Item	100,000 bushels storage, no additional dryer capacity	250,000 bushels storage 750 bushel per hour dryer
Storage bin	$35,000	$ 80,000
Dryer, installed	------	19,168
Aeration equipment	8,300	15,100
Conveyors	3,000	4,500
Leg	------	7,000
Subtotal	$46,300	$125,768
Plus 3 percent sales tax	1,389	3,773
Total	$47,689	$129,541

Table 42.

Estimated Annual On-Farm Total and Per Bushel Costs for Six Different Sizes of Continuous-Flow Dryers and Storage, 1972.

Cost	System 1*	System 2*	System 3*	System 4*	System 5*	System 6*
Dryer fuel, labor, and electricity	$ 875	$ 1,750	$ 1,750	$ 2,625	$ 2,625	$ 2,625
Handling	250	500	500	750	750	750
Additional shrinkage and quality deterioration	525	1,050	1,050	1,575	1,575	1,575
Property taxes	449	820	896	1,052	1,127	1,168
Insurance	374	684	747	876	939	973
Repairs	415	760	830	974	1,044	1,081
Annual depreciation and interest	2,557	4,676	5,106	5,994	6,425	6,654
Total expenses	$5,445	$10,240	$10,879	$13,846	$14,485	$14,826
Cost per bushel	$0.2178	$0.2048	$0.2176	$0.1846	$0.1931	$0.1977

*System 1 - 25,000 bushels storage, 180 bushel per hour dryer.
System 2 - 50,000 bushels storage, 180 bushel per hour dryer.
System 3 - 50,000 bushels storage, 360 bushel per hour dryer.
System 4 - 75,000 bushels storage, 180 bushel per hour dryer.
System 5 - 75,000 bushels storage, 360 bushel per hour dryer.
System 6 - 75,000 bushels storage, 550 bushel per hour dryer.

Table 43.

Estimated Elevator Costs and Revenues for 100,000 Bushel and 250,000 Bushel Additions, Without a Railroad, 1972.

	100,000 Bushel Addition	250,000 Bushel Addition
Sales volume (bushels)		
Corn	70,500	176,250
Soybeans	29,500	73,750
Revenue		
Handling margin		
Corn	$ 0	$ 0
Soybeans	1,180	2,950
Less: hauling	885*	2,213*
Total	$ 295	$ 737
Drying revenue	$5,288	$13,219
Service income		
Storage	4,350	10,875
Cleaning	260	650
Hedging revenue		
Corn	1,925	4,812
Soybeans	246	614
Gross income	$12,364	$30,907
Gross income per bushel	$.1236	$.1236
Expenses		
Depreciation and interest	$ 6,128	$17,351
Labor	500	1,250
Utilities	330	830
Property taxes	1,030	2,798
Insurance	858	2,332
Repairs	370	925
Drying costs	2,045	5,111
Total expenses	$11,261	$30,597
Cost per bushel	$.1126	$.1224
Net income	$ 1,103	$ 310
Net income per bushel	$ 0.011	$ 0.0012

* Trucking costs to local processors.

Table 44.

Estimated Elevator Costs and Revenues for a 100,000 Bushel Addition, on a Railroad, 1972.

	One Turnover of Sales Volume	One and One-half Turnovers of Sales Volume
Sales volume (bushels)		
Corn	70,500	105,750
Soybeans	29,500	44,250
Revenue		
Handling margins		
Corn	$ 2,115	$ 3,173
Soybeans	1,180	1,770
Less: hauling	221*	332*
Total	$ 3,074	$ 4,610
Drying revenue	$ 5,288	$ 7,931
Service income		
Storage	4,350	4,350
Cleaning	260	260
Hedging revenue		
Corn	1,925	1,925
Soybeans	246	246
Gross income	$15,143	$19,323
Gross income per bushel	$.1514	$.1288
Expenses		
Depreciation and interest	$ 6,128	$ 6,128
Labor	500	750
Utilities	330	495
Property taxes	1,030	1,030
Insurance	858	858
Repairs	370	370
Drying costs	2,045	3,067
Total expenses	$11,261	$12,698
Cost per bushel	$.1126	$.0847
Net income	$ 3,882	$ 6,625
Net income per bushel	$ 0.0388	$ 0.0442

* Additional trucking costs to local soybean processors.

Table 45.

Estimated Elevator Costs and Revenues for a 250,000 Bushel Addition, on a Railroad, 1972.

	One Turnover of Sales Volume	One and One-half Turnovers of Sales Volume
Sales volume (bushels)		
Corn	176,250	264,375
Soybeans	73,750	110,625
Revenue		
Handling margins		
Corn	$ 5,288	$ 7,931
Soybeans	2,950	4,425
Less: hauling	553*	830*
Total	$ 7,685	$11,526
Drying revenue	$13,219	$19,828
Service income		
Storage	10,875	10,875
Cleaning	650	650
Hedging revenue		
Corn	4,812	4,812
Soybean	614	614
Gross income	$37,855	$48,305
Gross income per bushel	$.1514	$.1288
Expenses		
Depreciation and interest	$17,351	$17,351
Labor	1,250	1,875
Utilities	830	1,245
Property taxes	2,798	2,798
Insurance	2,332	2,332
Repairs	925	925
Drying costs	5,111	7,667
Total expenses	$30,597	$34,193
Cost per bushel	$.1224	$.0912
Net income	$ 7,258	$14,112
Net income per bushel	$0.0290	$0.0376

* Additional trucking costs to local soybean processors.

Table 46.

Comparison of Estimated Per Bushel Drying and Storage Costs in Elevators and On-Farms, and Elevator Charges for Drying and 7 Months of Storage.

System	Cost per Bushel	Profit per Bushel
100,000 bushel elevator addition, without railroad	$.1126	$.0110
100,000 bushel elevator addition, with railroad, 1 turnover	.1126	.0388
100,000 bushel elevator addition, with railroad, 1.5 turnovers	.0847	.0442
250,000 bushel elevator addition, without railroad	.1224	.0012
250,000 bushel elevator addition, with railroad, 1 turnover	.1224	.0290
250,000 bushel elevator addition, with railroad, 1.5 turnovers	.0912	.0376
25,000 bushel on-farm storage, 180 bushel per hour dryer	0.2178	
50,000 bushel on-farm storage, 180 bushel per hour dryer	0.2048	
50,000 bushel on-farm storage, 360 bushel per hour dryer	0.2176	
75,000 bushel on-farm storage, 180 bushel per hour dryer	0.1846	
75,000 bushel on-farm storage, 360 bushel per hour dryer	0.1931	
75,000 bushel on-farm storage, 550 bushel per hour dryer	0.1977	
Typical elevator charge per bushel*	0.1788	

* Elevator charges based upon the following rates: storage 5¢ for the first 3 months, 1¢ for each additional month; drying 3¢ for the first 5 points of moisture removed, 0.5¢ for each additional point removed, 1.3¢ for additional shrinkage to 14.5 percent moisture.

Appendix C

Procedure for Estimating Variable Grain Handling and Expansion Costs at Subterminals

Estimated variable handling costs

The estimated cost per bushel for receiving, drying, storing and loading out grain for a subterminal was estimated from the annual audit of an actual train loading elevator during the period September 1, 1971 to August 31, 1972. Grain is the only product handled by this firm. During this period, the elevator handled 2.4 million bushels of grain and loaded out three one-hundred-car trains.

The assignment of costs to each grain handling activity in this organization was based on the manager's estimates of the proportion of each expense item attributable to each activity. The direct labor expense was allocated by the man-hours attributable to each activity times the respective wage rate. The remaining salaries and wages were allocated to administrative expense. Payroll taxes and employee benefits were allocated to the four grain handling activities and the administrative expense item by the same percentage as assigned to the total wages and salaries cost. The remaining variable expense items including repairs and maintenance, fuel, power and lights, were allocated to each process on the basis of the elevator manager's estimates of the proportion of the expense incurred by each activity.

The variable receiving cost per bushel at subterminals was estimated by dividing the cost of the items allocated to receiving by the number of bushels purchased.

The variable drying cost per bushel per point of moisture removed was estimated by dividing the costs assigned to drying by the number of bushels dried. The average drying cost per bushel per point of moisture removed was estimated by dividing this average cost per bushel by the average number of points of moisture removed.

The variable storage cost per bushel per month was estimated by dividing the costs allocated to storage by the average monthly ending inventory. Dividing this average yearly cost by 12 yields the average monthly storage cost by cost item.

The load out cost per bushel for 50 percent of the grain elevated for load out and 50 percent of the grain gravity flow (the existing conditions at the train-loading elevator) was estimated by dividing the costs allocated to load out by the number of bushels sold.

The load out cost per bushel for grain which was elevated was estimated by doubling the allocated cost from the audit for the repair and maintenance and fuel, and power and light costs. The additional elevation of 50 percent of the grain was assumed not to change the present labor and administrative expenses, given that additional elevating facilities were of adequate capacity.

In addition to estimating the average variable receiving cost over the entire year, the average variable cost of receiving was estimated for high volume receipt periods primarily at harvest time. During high volume receipt periods, the variable receiving cost per bushel for repairs and maintenance, administrative expense and fuel, power and lights were assumed to be the same as the yearly average. The direct labor cost per bushel received, including overtime, was significantly reduced from 1.03 cents per bushel to 0.61 cents per bushel. This reduced the total variable cost of receiving in high volume periods to 1.36 cents per bushel.

The marginal cost of receiving soybeans at the country elevators and at subterminals was based on the estimated cost of 1.78 cents per bushel for all time periods. The marginal cost of receiving corn at country elevators or subterminals includes the estimated receiving cost, 1.78 cents per bushel, plus an estimated drying cost of 0.28 cents per bushel per point of moisture removed. The following average number of points of moisture removed per bushel of corn receipts was assumed for each of the respective time periods: 10 points for the time periods October through December; 4 points for January through March; and no drying for the time periods April through September. The marginal cost of receiving, 1.78 cents per bushel, was assumed applicable to all multiple-car shipments except the guaranteed volume shipments. The marginal cost of receiving under the guaranteed volume shipments was assumed to be the estimated receiving cost in high volume periods, 1.3C cents per bushel.

The above estimated marginal receiving cost compares favorably with the 1.77 cents per bushel projected in a study of 168 country elevators conducted by the Economic Research Service of the USDA. The estimated marginal drying costs are also in close agreement with drying costs estimated in a study of 30 country elevator drying operations in Illinois.

Table 47.

Estimated Variable Costs of Receiving, Drying, Storing and Loading Out Grain at a Subterminal in Cents per Bushel.

Cost Item	Receiving		Drying		Storage		Load Out		
								Cost	
	Percent Allocated	Cost	Percent Allocated	Cost per point	Percent Allocated	Cost per month	Percent Allocated	50 Percent Elevated	100 Percent Elevated
Direct labor	67	1.03	16	.10	7	.05	10	.15	.15
Repairs and maintenance	28	.10	10	.02	50	.08	12	.04	.08
Fuel, power and lights	25	.13	20	.05	40	.09	15	.07	.15
Drier fuel	--	--	100	.11	--	--	--	--	--
Administrative expense	60	.52	--	--	20	.08	20	.17	.17
Insurance on grain	--	--	--	--	100	.04	--	--	--
Total cost per bushel		1.78		.28		.34		.43	.55

The marginal storage cost per month for corn and soybeans at country elevators and subterminals was assumed to include the estimated cost of 0.34 cents per bushel per month for labor, utilities, repairs, administrative expense and insurance on grain, plus an interest cost at 7 percent of 1.63 cents per bushel per month for soybeans (purchase price $2.80 per bushel) and 0.70 cents per bushel per month for corn (purchase price $1.20 per bushel). The 0.34 cents per bushel per month is slightly higher than the projected variable storage cost, 0.33 cents per bushel per month, in the USDA study.

The marginal cost of loading out corn or soybeans at country elevators was assumed to be 1.74 cents per bushel -- the projected load-out cost at country elevators in the USDA study. The marginal cost of load-out for corn or soybeans at subterminals for multiple-car shipments was assumed to be the estimated marginal cost of 0.55 cents per bushel. For single-car shipments the load-out cost was assumed to be 1.74 cents per bushel, the same as the country elevator.

Subterminal investment costs -- elevator expansion costs

Additional investments typically are required to expand existing elevator capacities into subterminal capacities. Estimates of the additional subterminal investment costs (i.e. elevator expansion costs) required over the 1971 capacities at the 26 alternative subterminal locations in the area were approximated by estimating the differences between the assumed required capacities to load the 50-, 80- and 115-car trains and the actual capacities existing in 1971.

The annual capital recovery costs were based on a 10 percent interest rate. The annual costs also included annual insurance and taxes on the facilities. Property taxes were computed at the rate of 80 mills on 27 percent of the initial installed cost -- approximately 2.1 percent of installed cost. The annual insurance cost on facilities and inventory was assumed to be 18 mills per dollar of installed cost. Insurance on facilities alone was assumed to be 15 mills per dollar of installed cost -- equivalent to 1.5 percent of installed cost.

Receiving costs

The expansion costs of grain receiving facilities were based on the estimated cost of facilities with 10,000 bushels per hour, 20,000 bushels per hour and 40,000 bushels per hour capacities. A semi-truck scale, scale house and office, and sampling equipment was estimated at $30,500 for the 10 and 20 thousand bushel per hour capacities. An additional truck scale, scale house and sampling equipment was added for the 40,000 bushels per hour capacity. The truck hoists were estimated at a cost of $6,000 per hoist, with a semi-hoist costing $25,000 needed for the 20 and 40 thousand bushel per hour capacities. Three, four and seven dump pits were assumed necessary for the 10, 20 and 40 thousand bushels per hour capacities, respectively. The first dump pit per leg was estimated to cost $6,000, each additional dump pit $5,500, and the semi-dump pit $8,000. The cost of the conveyors in the pits were estimated to be $110 per foot.

The cost of receiving legs varies by capacity and height. Two receiving legs were assumed necessary for the 10,000 bushels per hour rated capacity at a cost of $22,000. Three receiving legs were needed for the 20,000 bushels per hour rated capacity at a cost of $34,000 and four legs were assumed necessary for the 40,000 bushels per hour rated capacity at an estimated cost of $67,000. For each receiving leg, only the first part of the gallery belt to the first storage bin was assigned to receiving costs at an estimated cost of $110 per foot. Estimated installed and annual costs for receiving facilities are presented in Table 48.

Drying costs

The function used to estimate the expansion costs of drying facilities was based on the estimated cost of three, six and twelve thousand bushels per hour capacities rated at 10 point moisture removal. Drying facilities were assumed to include driers with 10 point moisture removal capacity, cleaners, legs, spouts, and conveyors from wet storage holding bins to the drier legs and back to the first dry storage bin. Estimated installed and annual costs for drying facilities are presented in Table 49.

Storage costs

The function used to estimate the expansion costs of storage facilities was based on the estimated cost of 300 thousand, 500 thousand and one million bushel storage facilities. Storage facilities included the cost of concrete storage bins and tunnel with top and bottom conveyors at a cost of $110 per foot, heat detection and aeration equipment. Land cost was also included in the storage facilities. A minimum of 4 acres of land at $2,500 per acre was assumed for the 300 and 500 thousand bushel facilities. An additional one-half acre of land was assumed necessary for every 250 thousand bushels of storage above the 500 thousand

Table 48.
Estimated Installed and Annual Cost of Receiving Facilities for Three Rated Capacities.

Cost Item	Years for Depreciation	10,000 Bushels/ Hour	20,000 Bushels/ Hour	40,000 Bushels/ Hour
Scale House and Office	20	$ 12,500	$ 12,500	$ 17,500
Truck Scale (s)	20	15,000	15,000	30,000
Sampler, Tester, etc.	5	3,000	3,000	6,000
Truck Hoists	20	18,000	43,000	61,000
Dump Pits	30	17,500	25,500	42,500
Belt in Pits	10	6,750	9,000	15,750
Legs	10	22,000	34,000	67,000
Distributors	10	8,375	8,375	16,750
Belt to 1st Storage Bin	10	4,400	6,600	8,800
Spouting and Miscellaneous	5	5,400	5,400	10,900
Total Installed Cost		$112,925	$162,375	$276,200
Annual Equivalent Cost	5 years	$ 2,216	$ 2,216	$ 4,458
	10 years	6,758	9,435	17,626
	20 years	5,344	8,281	12,744
	30 years	1,856	2,705	4,508
Annual Insurance and Tax @ 3.6% of Installed Cost		4,065	5,845	9,943
Total Annual Cost		$ 20,239	$ 28,482	$ 49,279

Installed cost (\$) = 56,014 + 5.478 (x bushels/hour).
Annual cost (\$) = 9,842 + 0.978 (x bushels/hour).

Table 49.

Estimated Installed and Annual Cost of Drying Facilities for Three Rated Capacities.

Cost Item	Years for Depreciation	3,000 Bushels/ Hour	6,000 Bushels/ Hour	12,000 Bushels/ Hour
Driers	10	$106,400	$212,800	$425,600
Cleaners	10	7,500	11,500	15,500
Legs, Conveyors and Spouts	10	17,500	28,000	52,000
Total Installed Cost		$131,400	$252,300	$493,100
Annual Equivalent Cost	10 years	$ 21,385	$ 41,062	$ 80,252
Annual Insurance and Tax @3.6% of Installed Cost		4,730	9,083	17,751
Total Annual Cost		$ 26,115	$ 50,145	$ 98,003

Installed cost ($) = 11,000 + 40.181 (x bushels/hour).
Annual cost ($) = 2,186 + 7.986 (x bushels/hour).

bushel facility. The estimated installed and annual costs for storage facilities are presented in Table 50.

Load-out cost

The expansion cost function for load out facilities was based on the estimated cost of 2, 10, 20 and 40 thousand bushels per hour load out capacities. Rail siding requirements for the 2, 10, 20 and 40 thousand bushels per hour capacities were assumed to be 10, 25, 50 and 115 hopper cars, respectively. Rail siding cost was estimated at $25 per foot for 1.5 times the required length to hold the specified number of rail cars. Switches were estimated at $4,000 per switch. A trackmobile or equivalent means of moving rail cars was assumed necessary for each size of load out facility at the cost listed in Table 51. The cost of load out conveyors and belts was assumed to include only a conveyor from the nearest storage bin to the load out leg at a cost of $110 per foot.

Table 50.

Estimated Installed and Annual Cost of Storage Facilities by Size of Capacity.

Cost Item	Years for Depreciation	300,000 Bushels	500,000 Bushels	1,000,000 Bushels
Silos and Tunnel	50	$210,000	$300,000	$550,000
Aeration and Heat Detection Equipment	10	10,500	17,000	28,000
Conveyors	10	16,720	33,440	66,880
Land	--	10,000	10,000	12,500
Total Installed Cost		$247,220	$360,440	$657,380
Annual Equivalent Cost	10 years	$ 4,430	$ 8,209	$ 15,442
	50 years	21,181	30,258	55,473
Annual Insurance and Tax @ 3.6% of Installed Cost		8,900	12,976	23,666
Total Annual Cost		$ 34,511	$ 51,443	$ 94,581

Installed cost ($) = 69,240 + 0.587 (x bushels).
Annual cost ($) = 8,638 + 0.086 (x bushels).

Table 51.

Estimated Installed and Annual Costs of Load Out and Cleaning Facilities by Size of Load Out Facility.

Cost Item	Years for Depreciation	2,000 Bushels/ Hour	10,000 Bushels/ Hour	20,000 Bushels/ Hour	40,000 Bushels/ Hour
Rail Siding & Switches	50	$30,500	$ 64,250	$124,500	$274,750
Trackmobile or Equivalent	15	10,000	25,000	25,000	50,000
Scales	20	5,800	18,000	30,000	60,000
Load out Legs and Belts	10	10,300	25,300	40,600	81,200
Cleaners	10	6,800	15,000	25,000	50,000
Spouts and Miscellaneous	5	3,900	4,900	5,900	11,800
Total Installed Cost		$67,300	$152,450	$251,000	$527,750
Annual Equivalent Cost	5 years	$ 1,029	$ 1,293	$ 1,556	$ 3,113
	10 years	2,783	6,559	10,676	21,353
	15 years	1,315	3,287	3,287	6,574
	50 years	3,076	6,480	12,557	27,711
Annual Insurance and Tax @ 3.6% of Installed Cost		2,423	5,488	9,036	18,999
Total Annual Cost		$10,626		$ 37,112	$ 77,750

Installed cost ($) = 30,950 + 12.1486 (x bushels/hour).
Annual cost ($) = 5,296 + 1.7696 (x bushels/hour).

Appendix D

ESTIMATED COSTS OF TRUCKING GRAIN BY INDEPENDENT TRUCKERS AND FARMERS

I. Methodology

II. Operating Costs of 810 Bushel Tractor-trailer Truck and 450 Bushel Truck for Average Trip Distance of 25 Miles

III. Operating Cost of 810 Bushel Tractor-trailer Truck for Average Trip Distance of 200 Miles

IV. Operating Cost of 300 Bushel Farm Truck

V. Operating Cost for 300 Bushel and 450 Bushel Wagons

I. Methodology

The basic model for estimating operating costs of 450 bushel trucks and 810 bushel tractor-trailer trucks contains three components; one is variable costs which are associated with trip distance, the second is fixed costs, and the third is transfer costs which are a function of the number of trips per year. The following equation reflects the total cost component:

$$TC_i = FC_i + VC_iX_i + TC_i \qquad i = 1, 4$$

where TC_i;	Total operating cost per year of i bushel truck
i = 1;	810 bushel tractor-trailer truck
i = 2;	450 bushel truck
i = 3;	300 bushel truck
i = 4;	wagon
FC_i =	Total fixed cost of i bushel truck or wagon
VC_i =	Total variable cost of i bushel truck or wagon
X_i =	Total annual mileage by i bushel truck or wagon
TC_i =	Total annual transfer cost of i bushel truck or wagon.

Fixed costs (FC) include interest, depreciation, license fees, insurance, management expenses, and highway use tax. Variable costs (VC) include fuel and oil, tires, wages, and maintenance and repair cost. Finally, transfer costs (TC) include the labor cost of loading and unloading waiting time.

Average cost per mile and per bushel mile per year for i^{th} bushel truck can be calculated by the following formulas:

Average cost per mile:

$$\frac{TC_i}{X_i} = \frac{1}{X_i}(FC_i + VC_iX_i + TC_i)$$

Average cost per bushel-mile;

$$\frac{TC_i}{X_iV_i} = \frac{1}{X_iV_i}(FC_i + VC_iX_i + TC_i).$$

Mr. Won W. Koo prepared much of this analysis.

where V_i; Total volume of grain to be hauled by i bushel truck.

The operating cost of a truck and wagon generally depends upon the annual mileage, trip distance, and speed. Therefore, the unique behavioral assumptions for operating each type of truck or wagon will be specified below. The type of vehicles are: 810 bushel tractor-trailer trucks, 450 bushel trucks, 300 bushel trucks, and 300 and 450 bushel wagons.

The data used in this analysis were collected from the various sources including truck and wagon dealers, tire dealers, state documents, and interviews with truck operators. This analysis is based on the actual 1972 price levels in Iowa.

II. Operating Cost for 450 Bushel and 810 Bushel Tractor-Trailer Trucks

The basic assumptions in this analysis are:

1. Each truck makes 4 trips per day and the average traveling distance is 25 miles per trip. 1/
2. There are 275 working days per year
3. Each truck travels 55,000 miles per year at 35 miles per hour

A. Fixed Cost

1. Interest and depreciation is based on an annual equivalent cost of 10% interest rate and 5 year life expectancy. Thus, the interest rate and depreciation on the investment for 450 bushel truck or 810 bushel tractor-trailer truck can be calculated by the following formula.

$$A.E.C. = P \frac{i (1 + i)^n}{(1 + i)^n - 1} - P_s \frac{i}{(1 + i)^n - 1}$$

where P = purchasing price

P_s = salvage value.

Purchase Price

Typical equipment assumed for 450 bushel and 810 bushel tractor-trailer trucks include:

1/ Number of trips per day obtained from actual experience of traveling 25 miles distance by C. Landy Philips, Manager, Farmers Coop Elevator Pierson, Iowa.

Options	810 Tractor-trailer	450
1. Air conditioned	no	no
2. Radio	yes	yes
3. Tinted glass	no	no
4. Engine	250-270 (diesel)	195 (diesel)
5. Tire	1100/20" (tractor)	1000/20" (back)
	700/20" (trailer)	700/20" (front)
6. Transmission	7 speed	7 speed

Purchase prices with above options were:

	Purchase Price	Salvage Value after 5 years
810 bu. (tractor)	$24,500	$7,500
(trailer)	6,800	3,400
450 bu.	14,000	3,500

Interest and depreciation (A.E.C.) for the 810 bushel tractor-trailer were computed as follows:

$$= \$31,300 \frac{0.1\ (1 + 0.1)^5}{(1 + 0.1)^5 - 1} - \$10,900 \frac{0.1}{(1 + 0.1)^5 - 1}$$

$$= \$31,300\ (0.264) - \$10,900\ (0.164)$$

$$= 8,263 - 1,787 = \$6,476 \text{ (per year)}.$$

Interest and depreciation (A.E.C.) for 450 bushel truck were computed as:

$$= \$14,000 \frac{0.1\ (1 + 0.1)^5}{(1 + 0.1)^5 - 1} - \$3,500 \frac{0.1}{(1 + 0.1)^5 - 1}$$

$$= \$14,000\ (0.264) - \$3,500\ (0.164)$$

$$= 3,696 - 574 = \$3,122 \text{ (per year)}.$$

2. License

The license fees are obtained from the following table of the Story County truck registration rate and weight as follows: 810 bushel tractor-trailer truck license fee is $1,260 per year , and 450 bushel truck license fee is $590 per year .

STORY COUNTY TRUCK RATES AND WEIGHTS

—(Effective Jan. 1, 1970 (Dec. 1, 1969 for Renewal of 1970 Registration)—

GROSS TONNAGE	TRACTOR ANNUAL FEE	½ ANNUAL FEE	MAXIMUM GROSS WEIGHT TRUCK, TRUCK-TRAILER, OR TRACTOR-TRAILER COMBINATION 5% OVERLOAD	25% OVERLOAD
3 Tons	$ 35.00*		6300 Lbs.	7500 Lbs.
4 Tons	45.00		8400 Lbs.	10000 Lbs.
5 Tons	60.00		10500 Lbs.	12500 Lbs.
6 Tons	75.00	37.50	12600 Lbs.	15000 Lbs.
7 Tons	100.00	50.00	14700 Lbs.	17500 Lbs.
8 Tons	135.00	67.50	16800 Lbs.	20000 Lbs.
9 Tons	170.00	85.00	18900 Lbs.	22500 Lbs.
10 Tons	205.00	102.50	21000 Lbs.	25500 Lbs.
11 Tons	240.00	120.00	23100 Lbs.	27500 Lbs.
12 Tons	275.00	137.50	25200 Lbs.	30000 Lbs.
13 Tons	310.00	155.00	27300 Lbs.	32500 Lbs.
14 Tons	345.00	172.50	29400 Lbs.	35000 Lbs.
15 Tons	380.00	190.00	31500 Lbs.	37500 Lbs.
16 Tons	415.00	207.50	33600 Lbs.	40000 Lbs.
17 Tons	450.00	225.00	35700 Lbs.	42500 Lbs.
18 Tons	485.00	242.50	37800 Lbs.	45000 Lbs.
19 Tons	520.00	260.00	39900 Lbs.	47500 Lbs.
20 Tons	555.00	277.50	42000 Lbs.	50000 Lbs.
21 Tons	590.00	295.00	44100 Lbs.	52500 Lbs.
22 Tons	625.00	312.50	46200 Lbs.	55000 Lbs.
23 Tons	660.00	330.00	48300 Lbs.	57500 Lbs.
24 Tons	695.00	347.50	50400 Lbs.	60000 Lbs.
25 Tons	735.00	367.50	52500 Lbs.	62500 Lbs.
26 Tons	775.00	387.50	54600 Lbs.	65000 Lbs.
27 Tons	815.00	407.50	56700 Lbs.	67500 Lbs.
28 Tons	855.00	427.50	58800 Lbs.	70000 Lbs.
29 Tons	895.00	447.50	60900 Lbs.	72500 Lbs.
30 Tons	935.00	467.50	63000 Lbs.	75000 Lbs.
31 Tons	975.00	487.50	65100 Lbs.	77500 Lbs.
32 Tons	1,015.00	507.50	67200 Lbs.	80000 Lbs.
33 Tons	1,055.00	527.50	69300 Lbs.	82500 Lbs.
34 Tons	1,120.00	560.00	71400 Lbs.	85000 Lbs.
35 Tons	1,160.00	580.00	73500 Lbs.	87500 Lbs.
36 Tons	1,200.00	600.00	75600 Lbs.	90000 Lbs.
37 Tons	1,240.00	620.00	77700 Lbs.	
38 Tons	1,280.00	640.00	79800 Lbs.	
39 Tons	1,320.00	660.00	81900 Lbs.	
40 Tons	1,360.00	680.00	84000 Lbs.	
41 Tons	1,400.00	700.00	86100 Lbs.	
42 Tons	1,440.00	720.00	88200 Lbs.	
43 Tons	1,480.00	740.00	90300 Lbs.	

*Fee reduced to $25.00 after ten full registrations.

Trailer Annual Fee

x-plate (12 ton)	y-plate (>12 ton)
$30	$60

JOHN A. O'DONNELL
STORY COUNTY TREASURER

BOONE BLANK BOOK CO., BOONE, IOWA 30558-69

3. Insurance

Insurance depends on the amount of coverage. In this analysis, $1,500 per year is assumed as an insurance payment for liability and collision for the 810 bushel tractor-trailer truck and $750 is assumed for the 450 bushel truck.

4. Management Expenses

Management expenses for operating truck will not vary with the level of production. In this study, total management costs of $150 per year were assumed for each truck.

5. Highway Use Tax

Highway use tax is obtained from the following Form 2290 (Federal Use Tax Return on Highway Motor Vehicles). Highway use tax is $220 per year for the 810 bushel tractor-trailer truck and $120 for the 450 bushel truck.

Form 2290
(Rev. June 1972)
Department of the Treasury
Internal Revenue Service

Federal Use Tax Return on Highway Motor Vehicles

For the Tax Period July 1, 1972 Through June 30, 1973

Name | Employer identification number

Address (Number and street)

YOUR COPY

City or town, State and ZIP code

1. File a separate Form 2290 for EACH MONTH in which a vehicle is FIRST USED IN THIS YEAR. This return covers vehicles FIRST USED IN THE MONTH OF .... 19.... . 2. Have you filed a Form 2290 for any other month of this taxable year? . . . ☐ Yes ☑ No. 3. Are all vehicles owned by you registered in the State indicated above? ☐ Yes ☐ No. *If answer is "No," attach a statement showing where and by whom such vehicles are registered.*

	Category	Type of Vehicle If your vehicle falls within one of the categories shown below, you are required to file this return. The tax in column (1) is based on the "taxable gross weight." (See definitions and instructions.)	Annual rate for vehicles used any time during July (1)	Rate of tax if first used after July (See table on page 4) (2)	Number of vehicles (3)	Amount of tax (Col. (1) or (2) times Col. (3)) (4)
Single Units	A	2 axled truck equipped for use as a single unit with actual unloaded weight of 13,000 pounds or more	$81.00			
	B	3 axled truck equipped for use as a single unit with actual unloaded weight of 13,000 pounds or more and less than 16,000 pounds	90.00			
	C	3 axled truck equipped for use as a single unit with actual unloaded weight of 16,000 pounds or more	120.00			
	D	4 axled truck equipped for use as a single unit with actual unloaded weight of less than 22,000 pounds	165.00			
	E	4 axled truck equipped for use as a single unit with actual unloaded weight of 22,000 pounds or more and less than 30,000 pounds	204.00			
	F	4 axled truck equipped for use as a single unit with actual unloaded weight of 30,000 pounds or more	240.00			
	G	More than 4 axled truck equipped for use as a single unit (see instructions)				
Tractor-trailer Combinations	H	2 axled truck-tractor with actual unloaded weight of 5,500 pounds or more and less than 7,000 pounds	90.00			
	I	2 axled truck-tractor with actual unloaded weight of 7,000 pounds or more and less than 9,500 pounds	120.00			
	J	2 axled truck-tractor with actual unloaded weight of 9,500 pounds or more and less than 11,000 pounds	150.00			
	K	2 axled truck-tractor with actual unloaded weight of 11,000 pounds or more	180.00			
	L	3 or 4 axled truck tractor with actual unloaded weight of less than 13,000 pounds	195.00			
	M	3 or 4 axled truck-tractor with actual unloaded weight of 13,000 pounds or more and less than 17,000 pounds	210.00			
	N	3 or 4 axled truck-tractor with actual unloaded weight of 17,000 pounds or more	222.00			
	O	More than 4 axled truck-tractor (see instructions)				
Truck-trailer Combinations	P	2 axled truck with actual unloaded weight of 9,000 pounds or more and less than 12,000 pounds and equipped for use in combinations	120.00			
	Q	2 axled truck with actual unloaded weight of 12,000 pounds or more and equipped for use in combinations	165.00			
	R	3 or 4 axled truck with actual unloaded weight of less than 14,000 pounds and equipped for use in combinations	195.00			
	S	3 or 4 axled truck with actual unloaded weight of 14,000 pounds or more and less than 19,000 pounds and equipped for use in combinations	222.00			
	T	3 or 4 axled truck with actual unloaded weight of 19,000 pounds or more and equipped for use in combinations	228.00			
	U	More than 4 axled truck equipped for use in combinations (see instructions)				
Buses	V	Tax applies to a bus having a taxable gross weight of more than 26,000 pounds. Taxable gross weight is actual unloaded weight plus 150 pounds for each unit of seating capacity provided for passengers and driver. Attach schedule showing computation of tax.	$3.00 per 1000 lbs. [illegible]			

4. Total amount of tax on vehicles put in use this month. This amount is payable with the return if the installment privilege is not elected or if the return covers vehicles first used in April, May, or June . . . . ______

5. Amount due if installment privilege is elected. If the return covers vehicles first used in { July, August, or September, enter $\frac{1}{4}$ of line 4; October, November, or December, enter $\frac{1}{3}$ of line 4; January, February, or March, enter $\frac{1}{2}$ of line 4 } . . . .

B. Variable Cost

1. Fuel and Oil Cost

The assumptions used for calculating fuel and oil cost are as follows:

(1) Each truck has a diesel engine

(2) Diesel fuel mileage is 4 miles per gallon for 810 bushel tractor-trailer truck and 5.7 miles per gallon for 450 bushel truck.

The price of diesel fuel is \$0.27 per gallon. Thus, fuel cost per mile can be calculated from the above assumptions by using the following formula:

$$\text{Fuel cost/mile} = \frac{\text{Fuel price per gallon}}{\text{Fuel mileage per gallon}}$$

Fuel cost per mile for 810 bushel tractor-trailer truck:

$$= \frac{\$0.27}{4} = \$0.068$$

Fuel cost per mile for 450 bushel truck:

$$= \frac{\$0.27}{5.7} = \$0.047.$$

It is assumed that the cost of oil for one oil change is \$7.80 and oil is changed every 4000 miles for both size trucks. Thus, oil cost per mile for both 810 bushel tractor-trailer truck and 450 bushel truck are as follows:

$$\text{Oil cost/mile} = \frac{\text{Oil cost per oil change}}{\text{Oil change mileage}}$$

$$= \frac{\$7.80}{4000} = \$0.002.$$

Hence, fuel and oil costs are:

810 bushel tractor-trailer truck = \$0.070 (per mile)

450 bushel truck = \$0.049 (per mile).

2. Tire Cost

The following table shows the price of tires and tire life expectancy.

Size of tire	Location	Price	Life
1000/20" 12 ply.	Rear	$120	100,000
1100/20" 12 ply.	Rear	130	88,000
700/20" 10 ply.	Front	76	50,000

Source: Tire dealers

The 810 bushel tractor-trailer truck has 16 units of 1100/20" 12 ply tires and 2 units of 700/20" 10 ply tires. The 450 bushel truck has 10 units of 1000/20" 12 ply tires.

Thus, the tire cost per mile for both size trucks can be calculated by the following formula:

$$\text{Tire cost/mile} = \frac{\text{(price of a unit of tire) x (number of tires per truck)}}{\text{tire life expectancy}}$$

Tire cost per mile for 810 bushel tractor-trailer truck

$$= \frac{(\$130 \times 16)}{88{,}000} + \frac{\$76 \times 2}{50{,}000} = \$0.027$$

Tire cost per mile for 450 bushel truck

$$= \frac{\$120 \times 10}{100{,}000} = \$0.012 .$$

3. Wages

It is assumed that average speed per hour is 35 miles and the average wage is $4.50 per hour. Thus, wage per mile for both 810 bushel tractor-trailer truck and 450 bushel truck can be calculated as follows:

$$\text{Driver's wage/mile} = \frac{\text{Average wage per hour}}{\text{Average speed per hour}} .$$

Driver's wage per mile for both 810 bushel tractor-trailer truck and 450 bushel truck:

$$= \frac{\$4.50}{35} = \$0.129 .$$

4. Maintenance and Repair Cost

Maintenance and repair cost per year is assumed to be 5% of the cost of truck every year. Thus, annual maintenance and repair costs per mile for the 810 bushel tractor-trailer truck and 450 bushel truck are as follows:

$$\text{Maintenance and repair cost/mile} = \frac{\text{(Cost of truck) x 5\%}}{\text{Total annual mileage}}$$

$$\text{810 bushel tractor-trailer truck} = \frac{\$31{,}300 \times 5\%}{55{,}000} = \$0.028$$

$$\text{450 bushel truck} = \frac{\$14{,}000 \times 5\%}{55{,}000} = \$0.013.$$

C. Transfer Cost

The loading and unloading wages are assumed to be $4.50 per hour for both 810 bushel tractor-trailer truck and 450 bushel truck. Thus, total transfer cost is obtained by multiplying number of total trips per year by loading and unloading wage per trip.

Under the assumptions of 4 trips per day and average trip distance of 25 miles, actual miles driven per day is 200 miles. Thus, the actual driving hour can be calculated by the following formula:

$$\text{Actual driving hour} = \frac{\text{Actual miles driven per day}}{\text{Average speed per hour}}$$

$$= \frac{200}{35} = 5.71 \text{ hours.}$$

Actual loading and unloading waiting time is calculated as follows with assumption of 8 hours work per day.

Actual loading and unloading waiting time per day

= total working hour - actual driving hour

= 8.00 - 5.71 = 2.29 hours/day.

Actual loading and unloading waiting time per trip

$$= \frac{2.29}{4} = 0.572 \text{ hour (34 minutes).}$$

Thus, transfer costs for both size of trucks (per year) are calculated by the following formulas:

Transfer cost for both size of truck per year

= (total No. of trips per year) x (Loading and unloading waiting wage per trip).

Transfer cost for 810 bushel tractor-trailer truck and 450 bushel truck:

$$= \frac{55,000}{50} \times \frac{34}{60} \times \$4.50 = \$2,805.$$

D. Total Operating Costs for 810 Bushel Tractor-trailer and 450 Bushel trucks are:

	450 Bushel Truck	810 Bushel Tractor-Trailer
1. Fixed Cost		
a. A.E.C.	$3,122.00	$6,476.00
b. License	590.00	1,260.00
c. Insurance	750.00	1,500.00
d. Management expenses	150.00	150.00
e. Highway use tax	120.00	220.00
Total	$4,732.00	$9,606.00
2. Variable Cost		
a. Fuel and oil	$0.049	$0.070
b. Tire	0.012	0.027
c. Wage	0.129	0.129
d. Maintenance and repair	0.013	0.028
Total	$0.203	$0.254
3. Transfer Cost	$2,805.00	$2,805.00
4. Average cost per running mile	$0.340	$0.480
5. Average round trip cost/bushel-mile	$0.00151	$0.00118.

III. Operating Cost for 810 Bushel Tractor-Trailer Truck for 200 Mile Distance

The basic assumptions in this analysis are:

1. This truck makes 1 trip per day and average trip distance is 400 miles round trip.
2. There are 275 working days per year.
3. This truck travels 110,000 miles per year at 55 miles per hour.

A. Fixed Costs

All fixed costs except the interest and depreciation are the same as for 810 bushel tractor-trailer truck in section II. Interest and depreciation is based on an annual equivalent cost of 10% interest rate and 4 years life expectancy. It is also assumed that the salvage value of 810 bushel tractor-trailer truck is \$8,900. Thus, the annual equivalent cost of the 810 bushel tractor-trailer trucks can be calculated by the formula used in section II. Interest and depreciation (A.E.C.) for the 810 bushel tractor-trailer was computed as follows:

$$= \$31,300 \quad \frac{0.1\ (1 + 0.1)^4}{(1 + 0.1)^4 - 1} \quad - \$8,900 \quad \frac{0.1}{(1 + 0.1)^4 - 1}$$

$$= \$31,300\ (0.315) - \$8,900\ (0.215)$$

$$= \$9,859.50 - \$1,913.50 = \$7,938.$$

B. Variable Cost

The per mile cost of fuel and oil and tires in this long distance operation are the same as the fuel and oil, and the tire cost of 810 bushel tractor-trailer truck in section II.

It is assumed that average speed per hour is 55 miles and the average wage is \$4.50 per hour. Thus, wage per mile for 810 bushel tractor-trailer truck can be calculated as follows:

$$\text{Driver's wage per mile} = \frac{\text{Average wage per hour}}{\text{Average speed per hour}}$$

$$= \frac{\$4.50}{55} = \$0.082.$$

C. Maintenance and Repair Cost

Maintenance and repair cost per year is assumed to be 5% of the cost of truck every year. Thus, annual maintenance and repair cost per mile for the 810 bushel tractor-trailer truck are as follows:

$$\text{Maintenance and repair cost per mile} = \frac{\text{cost of truck x 5\%}}{\text{total annual mileage}}$$

$$= \frac{\$31,300 \text{ x } 5\%}{110,000} = \$0.014.$$

D. Transfer Cost

The loading and unloading wages are assumed to be \$4.50 per hour for 810 bushel tractor-trailer truck. Thus, total transfer cost is obtained by multiplying number of total trips per year by loading and unloading wage per trip. Under the assumption of 1 trip per day and the average trip distance of 200 miles, actual miles driven per day is 400 miles. Thus, the actual driving hours can be calculated by the following formula:

$$\text{Actual driving hours} = \frac{\text{Actual mileage driven per day}}{\text{Average speed per hour}}$$

$$= \frac{400}{55} = 7.27.$$

The actual loading and unloading waiting time is obtained by subtracting the actual driving hours from the total working hours per day (8 hours).

Actual loading and unloading waiting time per day

= 8.00 - 7.27 = 0.73 (hours per day)

= 43.8 minutes per trip.

Thus, the total transfer cost for 810 bushel tractor-trailer truck per year is calculated by the following formula:

Transfer cost = (Total number of trips per year) x (loading and unloading wage per trip)

$$= \frac{110{,}000}{400} \times \frac{43.8}{60} \times \$4.50 = \$903.38.$$

E. Total Operating Costs for 810 Bushel Tractor-trailer Truck are:

1. Fixed cost

a. A.E.C.	\$ 7,938
b. License	1,200
c. Insurance	1,500
d. Management expenses	150
e. Highway use tax	220
Total	\$11,008

2. Variable cost

a. Fuel and oil	\$0.070
b. Tire	0.027
c. Wage	0.082
d. Maintenance and repair	0.014
Total variable cost	\$0.193

3. Transfer cost $903.38
4. Average cost per running mile $0.3011
5. Average round trip cost/bushel mile $0.00074.

IV. Operating Cost for 300 Bushel Farm Trucks

The basic assumptions in this analysis are:

1. Each truck will travel 2,000 miles per year at 20 miles per hour.
2. The average trip distance is 6 miles.

A. Fixed Cost

1. Interest and depreciation

Based on an annual equivalent cost at 10% interest rate and 10 year life expectancy, the interest rate and depreciation on the investment for the 300 bushel truck can be calculated by the following formula:

$$A.E.C. = P \frac{i(1+i)^n}{(1+i)^n - 1} - P_s \frac{i}{(1+i)^n - 1}$$

where P = purchasing price

P_s = salvage value.

Thus, annual depreciation and interest (A.E.C.)

$$= \$7,500 \frac{0.1(1+0.1)^{10}}{(1+0.1)^{10} - 1} - \$1,155 \frac{0.1}{(1+0.1)^{10} - 1}$$

$$= \$7,500\ (0.163) - \$1,155\ (0.063) = \$1,149.73 \text{ (per year)}$$

where $7,500 = purchase price

$1,155 = salvage value at the end of 10 years.

2. License

License fees were calculated from a table of Story county truck rate and weight, Iowa. License fee for gross weight of 13 tons is $310 per year.

3. Insurance

Insurance depends on the amount of coverage. In this analysis an annual insurance payment for 300 bushel truck is assumed to be $150 per year.

B. **Variable Cost**

1. **Fuel and oil cost**

Assumptions used for calculating fuel and oil cost are as follows:

a. The 300 bushel truck has a gasoline fuel engine

b. Average mileage is 6.9 miles per gallon.

c. The price of gas fuel is $0.35 per gallon; thus, gas fuel cost per mile can be calculated as follows:

$$\text{Gas fuel cost per mile} = \frac{\text{Gasoline price per gallon}}{\text{Gasoline mileage per gallon}}$$

$$= \frac{\$0.35}{6.9} = \$0.051.$$

It is also assumed that the cost of oil for oil change is $7.80 including the oil filter and that oil is changed every 6,000 miles. Thus, the cost of oil and oil filter per mile is:

$$\text{Oil and oil filter per mile} = \frac{\$7.80}{6{,}000} = \$0.001$$

Hence, fuel and oil cost is $0.052 per mile.

2. **Tire Cost**

The price of tires for the 300 bushel truck and the life of the tires are assumed as follows:

Tire cost per unit = $97

Tire life = 28,000 miles.

Thus, tire cost per mile is calculated as follows:

$$\text{Tire cost per mile} = \frac{(\text{Tire price/unit}) \times (\text{Number of tire/truck})}{\text{Tire life expectancy}}$$

$$= \frac{\$97 \times 6}{28{,}000} = \$0.021.$$

3. **Wages**

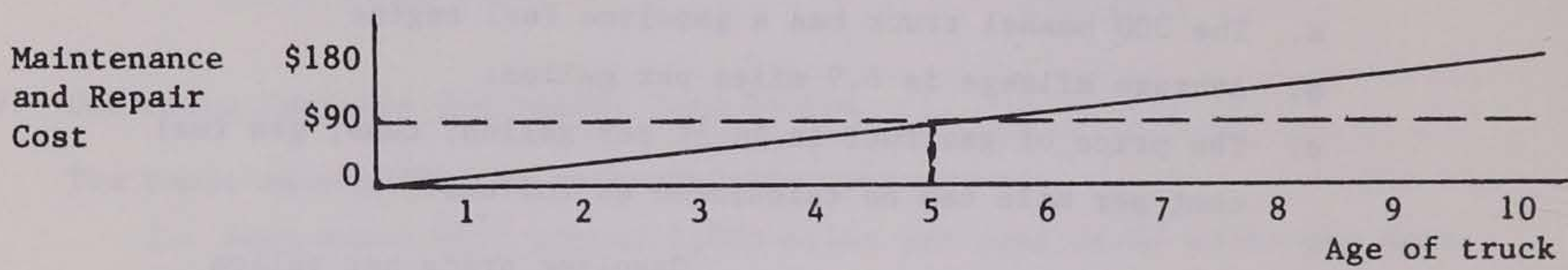
It is assumed that the driver's wage per hour is $2.00 and that average speed per hour is 20 miles per hour. Thus, the driver's wage per mile can be calculated as follows:

$$\text{Driver's wage per mile} = \frac{\text{Average wage per hour}}{\text{Average speed per hour}}$$

$$= \frac{\$2.00}{20} = \$0.10\ .$$

4. Maintenance and Repair Cost

Maintenance and repair cost depends on the age of truck as the following diagram shows:



Average maintenance and repair cost is estimated to be $90 per year. Thus, maintenance repair cost per mile can be calculated as the following:

$$\text{Maintenance and repair cost per mile} = \frac{\text{Average maintenance and repair cost per year}}{\text{Annual driving mileage}}$$

$$= \frac{\$90}{2000} = \$0.045.$$

C. Transfer Cost

No loading time was charged to the farmer-owned 300 bushel truck or to the tractor wagon combination because these vehicles were assumed to be loaded in the field and these costs are more appropriately charged to the cost of grain production. It is assumed that unloading time is 20 minutes per trip and unloading wage is $2.00 per hour. Thus, unloading cost can be calculated by the following formula:

$$\text{Transfer cost} = \frac{\text{Total annual mileage}}{\text{Round trip distance}} \quad \text{Loading and unloading wage per trip}$$

$$= \frac{2000 \text{ mi.}}{12 \text{ mi.}} \times \frac{20}{60} \times \$2.00 = \$111.$$

D. Operating Cost for 300 Bushel Truck

1. Fixed cost

a.	A.E.C.	$1,149.73
b.	License	310.00
c.	Insurance	150.00
	Total	$1,609.73

2. Variable cost

a. Fuel and oil	\$0.052
b. Tire	0.021
c. Wage	0.100
d. Maintenance and repair	0.045
	\$0.218

3. Transfer cost — \$111.00

4. Average cost per running mile — \$1.078

5. Average round trip cost per bushel-mile — \$0.0072

V. Operating Cost for 300 Bushel and 450 Bushel Wagons

The basic assumptions in this analysis are:

1. Wagons will travel 1000 miles per year at 12 miles per hour.
2. The tractor has been purchased for field work and only variable costs are charged to the grain hauling function.

A. Fixed Cost

Interest and depreciation on the wagon is based on an annual equivalent cost of 10% interest rate and 12 year life expectancy. Thus, the interest rate and depreciation on the investment of 450 bushel and 300 bushel wagon can be calculated by the following formula:

$$A.E.C. = P \frac{i(1+i)^n}{(1+i)^n - 1} - P_s \frac{1}{(1+i)^n - 1}$$

where P = purchasing price

P_s = salvage value .

Actual purchase price of wagon can be calculated under assumption of 20% price discount.

The list and the actual price of 300 and 450 bushel wagon are as follows:

Size of Wagon		Box	Gear	Side Board	List Price	Actual Price
300 bu.	W.O.B.	\$445	\$538	\$64	\$1047	\$ 838
	W.B.	445	751	64	1260	1008
450 bu.	W.O.B.	745	694	80	1519	1215
	W.B.	745	904	80	1729	1383

where

W.O.B. = without brakes

W.B. = with brakes.

The life of the wagon is assumed to be 12 years with no salvage value. Thus, the annual equivalent cost, i.e. interest at 10% per year and depreciation for the wagons is:

Size of Wagon	Annual Equivalent Cost
300 bu. W.O.B.	\$ 838 x 0.1468 = \$123.02
300 bu. W.B.	1,008 x 0.1468 = 147.97
450 bu. W.O.B.	1,215 x 0.1468 = 178.36
450 bu. W.B.	1,383 x 0.1468 = 203.02

The insurance on the tractor and wagon are covered by blanket insurance policy and no license fees are assessed on farm implements. Thus, there are no additional fixed cost.

B. Variable Cost for Wagon

1. Tires are assumed to be replaced at the end of seven years. The tire cost per mile for each size of wagon can be calculated by the following formula:

$$\text{Tire cost per mile} = \frac{(\text{Price of a unit of tire}) \times (\text{Number of tire per wagon})}{\text{Tire life expectancy}}$$

Tire price of 300 bu. wagon = \$ 90 per unit

Tire price of 450 bu. wagon = \$173 per unit.

Thus, annual tire cost per mile for 300 bushel wagon

$$= \frac{\$360}{7 \times 1000} = \$0.051$$

and

annual tire cost per mile for 450 bushel wagon

$$= \frac{\$692}{7 \times 1000} = \$0.099.$$

2. Maintenance and Repair Cost

There is no maintenance and repair cost for the first seven years. Maintenance and repair cost are assumed to appear after seven years, but it would be a small cost, it is ignored in this analysis.

C. **Variable Cost for Tractor**

1. **Fuel and Oil Cost**

The price of diesel is $0.27 per gallon. Fuel consumption for each type tractor is estimated as follows:

Type of Tractor	Fuel Consumption Per Hour (gallons)
110 H.P.	4.94
140 H.P.	6.15

The average speed of these tractors is assumed to be 12 miles per hour. Thus, fuel consumption per mile can be calculated by the following formula:

$$\text{Fuel consumption} = \frac{(\text{Fuel consumption per hour}) \times (\text{price})}{\text{Speed per hour}}$$

Fuel consumption per mile:

$$= \frac{4.94 \times \$0.27}{12} = 0.111 \text{ (110 H.P.)}$$

$$= \frac{6.15 \times \$0.27}{12} = 0.138 \text{ (140 H.P.).}$$

Oil is assumed to be changed every 120 driving hours. The cost of oil change including oil filter is $9.80 for 110 H.P. and $10.40 for 140 H.P. Thus, the oil cost per mile by size of tractor is as follows:

The oil cost per mile for 110 H.P. tractor

$$= \frac{\$9.80}{(120) \times (12)} = \$0.0068$$

The oil cost per mile for 140 H.P. tractor

$$= \frac{\$10.40}{(120) \times (12)} = \$0.007 .$$

Hence, fuel and oil cost per mile is

Size of tractor	Fuel and oil cost
110 H.P.	$0.118
140 H.P.	0.145

2. Driver's wages

Driver's wages for farm tractor is assumed to be $2.00 per hour for 110 H.P. tractor and $3.00 per hour for 140 H.P. tractor. Thus, the driver's wage per mile by size of tractor can be calculated as follows:

Driver's wage for 110 H.P. tractor =

$$= \frac{\text{Wage per hour}}{\text{Average speed per hour}} = \frac{\$2.00}{12} = \$0.167$$

Driver's wage for 140 H.P. tractor =

$$= \frac{\text{Wage per hour}}{\text{Average speed per hour}} = \frac{\$3.00}{12} = \$0.250.$$

3. Tire Cost

Tires are assumed to be replaced at the end of five years. The price of tires for farm tractors is as follows:

Size of tractor	Front (2 unit)	Rear (2 unit)	Total	Cost per Year
110 H.P.	$109	$648	$757	$151.40
140 H.P.	136	840	976	195.20

For one acre of land, 135 minutes of tractor time is used to produce the crop and 16.5 minutes to ship grain. So, grain hauling time is only 12% of total tractor time.

The cost of tire which is used for shipping grain can be calculated by the following formula:

$$\text{Weighted tire cost per mile} = \frac{\text{(Tire cost per year) x (Weight)}}{\text{Annual mileage of grain}} .$$

Thus, weighted tire cost per mile for hauling grain is $0.018 for 110 H.P. tractor and $0.023 for 140 H.P. tractor.

4. Maintenance and repair cost

Since only 12% of total tractor hour is estimated to be used for hauling grain, no maintenance and repair cost is included in this analysis.

D. Transfer Cost

The unloading cost is assumed to be $2.00 per hour. Since an annual trip

mileage of 1000 miles and an average trip distance of 6 miles are already **assumed in this study, transfer costs are** the same for all size of tractors.

Transfer cost is \$167 per year = $(\frac{1000}{12} \times \$2.00)$.

E. Operating cost of 450 bushel and 300 bushel wagon

	One 110 H.P. Tractor two 300 bu. wagon (W.B.)	One 140 H.P. Tractor two 450 bu. wagon (W.B.)
1. Fixed cost		
A.E.C.	\$295.94	\$406.04
2. Variable cost		
Wagon		
Tire	\$ 0.051	\$ 0.099
Tractor		
Fuel and oil	\$ 0.118	\$ 0.145
Driver's wage	0.167	0.250
Tires	0.018	0.023
Maintenance and repairs	--	--
Total variable cost	\$ 0.354	\$ 0.517
3. Transfer cost	\$167.00	\$167.00
4. Average cost per running mile	\$ 0.817	\$ 1.090
5. Average round trip cost per bushel-mile	\$ 0.00272	\$ 0.00242

Appendix E

Estimated Barge Costs

The purpose of this analysis is to detail the 1972 cost of shipping grain by barge from Dubuque, Iowa and from St. Louis, Missouri to New Orleans, Louisiana.

I. Dubuque to New Orleans

A. Investment Costs

Jumbo covered hopper barge
Cost $125,000
Salvage value $1,000
Useful life 23 years
Interest rate 10%

Annual equivalent cost i.e., present value annual cost to recover the initial investment of a jumbo covered barge at a 10% interest rate.

= ($125,000) (0.11257) - ($1,000) (0.01257)

= 14,071.25 - 12.57

= 14,058.68 per year

= $38.52 per day

Round trip cost =

($38.52) (50 days round trip) = $1,926.00.

B. Towing Costs.

1. <u>Dubuque to St. Louis</u>

Assume 3200 HP tow boat
400 mile trip towing
10 loaded barges south bound

Down stream costs

1.5 mills per ton mile

Per barge cost = (1400 tons) (400 miles) (.0015) = $840 per barge

Upstream costs

(75 cents/mile) (400 miles) = $300 per barge

Round trip towing cost Dubuque to St. Louis and return =

$840 + $300 = $1,140.

2. St. Louis to New Orleans

Assume 7500 HP tow boat
35 loaded barges
1000 miles

Down Stream

0.5 mills per ton mile

Per barge cost = (1400 tons) (1050 miles) (.0005) = $735.00 per barge

Upstream

Per barge cost = (65 cents/mile) (1050 miles) = $682.50 per barge

Round trip towing cost St. Louis to New Orleans and return

= $735.00 + $682.50 = $1,417.50.

3. Total towing costs = $1,140 + $1,417.50 = $2,557.50.

C. Switching Charges (Dubuque to St. Louis to New Orleans and return)

Item	No. of Days	Cost per day	Total Cost
Load in Dubuque	2.0		
Move from elevator	0.5		$ 60
Fleet Dubuque	3.0	$6	18
Make up Dubuque	0.5		25
Move to St. Louis			
400 miles @ 5 mph.	3.3		
Break up St. Louis	0.5		25
Fleet St. Louis	2.5	6	15
Make up St. Louis	0.5		30
Travel to New Orleans			
1050 miles @ 8.1 mph.	5.4		
Break up New Orleans	0.5		30
Fleet New Orleans	5.0	8	40
Move to elevator	0.5		65
Unload New Orleans	2.0		
Move from elevator	0.5		65
Make up New Orleans	2.5		30
Travel to St. Louis			
1050 miles @ 4.6 mph.	9.5		
Break up St. Louis	0.5		25
Fleet St. Louis	3.0	6	18
Make up St. Louis	0.5		30
Travel to Dubuque			
400 miles @ 5 mph.	3.3		
Break up Dubuque	0.5		
Fleet Dubuque	3.0	6	25
Move to elevator	0.5		60
Total	50.0		$579

D. Other charges (Round trip)

1. Insurance

(1.50 per day) (50 days) = $75.00

2. Maintenance and repairs

(3.50 per day) (50 days) = $175.00

3. Administration and taxes

(9.00 per day) (50 days) = $450.00

4. Cleaning

Cost per trip = $100

5. Total other cost $800.00.

E. Cost per bushel Dubuque to New Orleans

1. Investment cost = $1,926.00

2. Towing cost = $2,557.50

3. Switching cost = $579.00

4. Total other costs = $800.00

Total round trip cost = $5,881.50.

F. Number of bushel hauled

Soybeans (1400 tons) (33.33) = 46,662

Corn (1400 tons) (35.71) = 49,994.

G. Total cost per bushel =

Total round trip cost = $3.9757/ton

Soybeans

$$= \frac{\$5,881.50}{46,662} = 12.60 \text{ cents per bushel}$$

Corn

$$= \frac{\$5,881.50}{49,994} = 11.76 \text{ cents per bushel.}$$

II. St. Louis to New Orleans

A. Investment Costs

Jumbo covered hopper barge
Cost $125,000
Salvage value $1,000
Useful life 23 years
Interest rate 10%

Annual equivalent cost i.e., present value annual cost to recover the initial investment of a jumbo covered barge at a 10% interest rate.

= ($125,000) (0.11257) - ($1,000) (0.01257)

= 14,071.25 - 12.57

= 14,058.68 per year

= $38.52 per day

Round trip cost =

($38.52) (35.4 days round trip) = $1,363.61.

B. Towing Costs

1. St. Louis to New Orleans

Assume 7500 HP tow boat
35 loaded barges
1000 miles

Down Stream

0.5 mills per ton mile

Per barge cost = (1400 tons) (1050 miles) (.0005) = $735.00 per barge

Upstream

Per barge cost = (65 cents/mile) (1050 miles) = $682.50 per barge

Round trip towing cost St. Louis to New Orleans and return

= $735.00 + $682.50 = $1,417.50.

C. Switching Charges (St. Louis to New Orleans and return)

Item	No. of Days	Cost per day	Total Cost
Load in St. Louis	2.0		
Move from elevator	0.5		$ 60
Fleet St. Louis	2.5	6	15
Make up St. Louis	0.5		30
Travel to New Orleans			
1050 miles @ 8.1 mph.	5.4		
Break up New Orleans	0.5		30
Fleet New Orleans	5.0	8	40
Move to elevator	0.5		65
Unload New Orleans	2.0		
Move from elevator	0.5		65
Make up New Orleans	2.5		30
Travel to St. Louis			
1050 miles @ 4.6 mph.	9.5		
Break up St. Louis	0.5		25
Fleet St. Louis	3.0	6	18
Move to Elevator	0.5		60
Total	35.4		$438

D. Other charges (Round trip)

1. Insurance

   (1.50 per day) (35.4 days) = $53.10

2. Maintenance and repairs

   (3.50 per day) (35.4 days) = $123.90

3. Administration and taxes

   (9.00 per day) (35.4 days) = $318.60

4. Cleaning

   Cost per trip = $100

5. Total other cost $595.60.

E. Cost per bushel St. Louis to New Orleans

1. Investment cost = $1,363.61
2. Towing cost = $1,417.50
3. Switching cost = $438.00
4. Total other costs = $595.60

   Total round trip cost = $3,814.71.

F. Number of bushel hauled

   Soybeans (1400 tons) (33.33) = 46,662

   Corn (1400 tons) (35.71) = 49,994.

G. Total cost per bushel =

   Total round trip cost = $3,814.71

   Soybeans

   $= \frac{\$3,849.22}{46,662} = \$8.18$ cents per bushel

   Corn

   $= \frac{\$3,849.22}{49,994} = \$7.63$ cents per bushel.

Appendix F

Procedure for Estimating Single and Multiple-Car Rail Costs of Transporting Grain

The rail costs used in this study are based upon costs published in Interstate Commerce Commission Statement No. 1C1-69, Rail Carload Cost Scales by Territories for the Year 1969, hereafter referred to as the "ICC Scale". This document is based upon an application of Rail Form A, reflecting the 1969 operations of all Class I line-haul railways assigned to one of seven rail cost territories defined within the document. The following four territories are employed by the present study: Region II (Official territory, excluding New England region), Region IV (Southern territory), Region V (Western Trunk Line; i.e., the Western district, excluding Mountain Pacific and Trans-territory) and Region VI (Mountain Pacific and Trans-territory).

Variable costs in the ICC Scale reflect costs which are considered to be a function of traffic over the long-run period and at average traffic densities. They

> include 80 percent of freight operating expenses, rents and taxes (excluding Federal income taxes) plus an allowance for the cost of capital before Federal income taxes on 50 percent of the road property and 100 percent of the equipment used in freight service. Fully allocated costs include, in addition to the variable costs as described above, all other revenue needs necessary to permit the carriers to cover the remaining 20 percent of the freight operating expenses, rents, and taxes, (excluding Federal income taxes), an allowance for capital before income taxes on the remaining property. These revenue needs over and above variable costs, identified as constant costs, were given a pro rata ton and ton-mile distribution over all revenue traffic, without distinction as to kind or class.

That is, fully allocated cost is defined to be variable cost plus an apportionment of the average contribution to overhead by all rail traffic.

The cost of capital is based upon the ratio of total interest payments to total outstanding debt. Rates of return on investment "were applied to the original cost of land and rights, road property and equipment, including an allowance for working capital, material and supplies, less back depreciation on total depreciable property, back amortization on road property and an estimated normal reserve on amortized equipment in lieu of the back figures".

A number of objections have been levied against the application of rail cost coefficients derived from Rail Form A. Two limitations inherent to Form A are subject to continuing criticism. First, as noted by the Commission,

> the formulas were initially designed mainly for the purpose of developing costs in the aggregate for transportation service conducted by large groups of carriers within certain territories or regions. Thus, the emphasis in these formulas has been upon, and the results achieved reflect, general overall average operations performed under average conditions. . . (Thus), when the costs of a specific carrier handling particular traffic between certain points are involved, the application of such formulas may not be appropriate without substantial adjustments and various refinements to reflect the peculiar situation under consideration.

Thus, costs estimated on the basis of regional averages may be inapplicable with respect to specific traffic moving between specific geographic points by a specific railroad at a specific point in time: the formulas and involved studies associated with Rail Form A may not fit the reality of a certain movement. Associated with this limitation is the argument against the use of any single, standardized cost formula to reflect a wide variety of rail operating conditions, as well as the observation that such a standardized methodology introduces rigidity into costing procedures.

The Commission has recognized this limitation, and has noted that generally,

> the formulas produce estimated costs based mainly upon historical data to which average factors, mirroring a hypothetical average carrier operating under average conditions, are applied. To the extent that the actual operations of a specific carrier may deviate from such average, the results may or may not be meaningful in the evaluation of a certain specific prospective situation. Although the present formulas may properly continue to be utilized as a point of departure and serve as general guides for cost analyses, the results should be considered no more than a rough measure of the true costs, unless substantial adjustments are made in the application of the formulas to reflect the particular conditions surrounding the specific transportation.

In the estimation of single car costs, the present study has utilized, to the extent possible, the adjustment provisions specified by the ICC Scale. These adjusted costs were then subjected to various assumptions to reflect the cost saving associated with various sizes of multiple-car shipments.

The second basic limitation of Form A relates to the assumption of an overall 80 percent variability factor applicable to freight operating expenses, rents, and taxes (excluding Federal income tax). Railroad cost analysts cautioned the present study team that this factor over- and underestimated the variability of some major cost elements. Moreover, they expressed concern that the variability factor did not consider separate accounts within total freight expense.

The Cost Finding Section of the Commission, however, has redesigned the rail cost formula in an attempt to alleviate these two problems. The ICC Scales for 1970--which became available after this research had been completed--is based upon a redesigned formula. The new formula provides new variability factors for separate, or for groups of, expense accounts; these factors range from 44 percent to 97 percent, and replace the overall 80 percent factor used previously. The ICC study

> examined the relationships between twelve subdivisions of these expenses and various measures of output levels. Percent variable factors were then computed individually, for twelve expense groups... The present study results, when applied to the 1970 expenses of all Class I line-haul railroads, produced an overall average percent variable of 76 percent as compared with the prior value of 80 percent.

The data used had been reported to the Commission by all line-haul railroads for the years 1966 through 1970.

A third limitation of the ICC Scale is that the formula specifies a constant line-haul cost per hundredweight-mile. There is some reason to believe that this formula tends to have an upward bias for long distance heavy-loading movements. For example, the actual wages of the conductor and the brakemen are based on the number of cars in the train regardless of the size of the car or the weight of the commodity being hauled. However, in the ICC Scale the cost of these trainmen is based on trailing gross ton-miles. Thus, the trainmen wage costs are biased upward for commodities such as grain in covered hoppers. While this bias is present in all movements, it tends to place a heavier weight on longer distance movements, since the line-haul costs become a larger portion of the total costs.

Despite these limitations of the ICC Scale, the present study had no alternative source of data for the rail cost analysis, since the scales are the most widely accepted and reliable source available for public use. However, the authors must acknowledge the willingness of the railroads operating in the study area to assist with the study in adjusting the cost scales and to assist throughout the planning, analytic, and writing stages of the present study.

The generation of single- and multiple-car costs for the present study relies upon adjustment of the Rail Carload Cost Scales by Territories for the Year 1969, published by the U.S. Interstate Commerce Commission, hereafter referred to as the "ICC Scale". A total of thirteen adjustments to the ICC Scales were made to accommodate single-car shipments from the study area. Various assumptions were then applied to the adjusted single-car cost coefficients to estimate the costs of various sizes of multiple-car grain shipments.

Single-car adjustments

The adjustments applied to the basic single-car cost coefficients appearing in Table 3 of the ICC Scale were as follows:

Item 9. Allowance for circuity.

The four railroads serving the study area provided data on the step-by-step physical movement of grain consignments--single- and multiple-car--originating at a representative sample of country elevator sites on their individual lines, and terminating at the markets under consideration. These data defined the actual route by which a consignment moves under a normal set of circumstances from each of the origins to each destination, and therefore, provided the "actual" (as distinguished from "short-line") total miles from each origin to each destination. Hence, no adjustment was required with respect to rail circuity. The matrix of actual mileages was calculated from the Rand McNally Handy Railroad Atlas of the United States.

Item 10. Treatment of loss and damage claim payments.

Carload unit costs in Table 3 of the ICC Scale exclude loss and damage claim payments. A study of a country elevator in the study area with official weight scales indicated a box car loss of 0.9536% of origin weight and a hopper car loss of 0.1938% of origin weight of grain, excluding one-eighth of 1% "shrink" on the origin weight for which a shipper may not claim a loss to the carrier. The representative per bushel prices of $1.2182 and $2.7967 for corn and soybeans, respectively, are herein assumed; these prices are based upon the pattern of 1970-71 Gulf prices. Item 10 has been adjusted to account for these losses.

Item 11. Average load by territory and by type of cars.
This study assumes that a box and hopper car is able to hold, respectively, 62.5 and 97.5 tons of corn and soybeans. These tonnages are consistent with those experienced by the above country elevator in the study area.

Item 12. Type of train.
Table 3 of the ICC Scale separates cost by type of train with respect to differences in weight of the trailing tons, the number of locomotive units, and wages of train and engine crew.

The definition of way and through trains follows that of Petroleum Rail Shippers' Association v. Alton and Southern Railroad et al. The total actual mileage from each origin to each destination was stratified into actual way train and through train miles under the assumption that once a consignment becomes part of a through train, it remains part of that train until it reaches its destination. In no case was the actual way mileage of a route assumed to exceed 100 miles. This analysis, therefore, did not employ the territorial average way train short-line miles appearing in the ICC Scales.

Item 14. Tare weight.
The study assumes a standard 40 foot box-general service unequipped car with tare weight of 25.1 tons, and a covered hopper car with tare weight of 32.5 tons. It is assumed that single-car traffic is composed of both types of equipment, and that multiple-car consignments move solely in hopper cars.

Item 15. Treatment of special services.
The term "special services" includes the per carload costs of train supplies and expenses, and station employees; the cost of special services is included in Table 3 of the ICC Scale. The present study assumes that this cost for box cars includes the cost of a grain door and station employees; no adjustments were made for hopper cars.

Item 17. Treatment of origin or destination portion of freight-train car costs.
Territorial variable cost per carload at either the point of origin or destination includes the following: freight-train car maintenance and related overhead, freight-train car depreciation, and

return on cost of freight-train cars other than mileage. The study substituted its own estimated ownership costs for the territorial variable cost of the ICC Scale; the estimation of ownership cost--including depreciation, return on investment, tax, and maintenance--of a box and hopper car assumes the following:

1. the 1972 purchase price of a box and hopper, respectively, is $16,500 and $18,500;
2. the service life of cars dedicated to single-car and 3 to 10 car shipments is 20 years,* while that of cars dedicated to 50 or more cars in a unit shipment is 15 years;
3. the salvage values of box and hopper cars are $2,000 and $2,500. This does not include an allowance for dismantling cars.
4. the annual tax on both types of car is $200;
5. a 10% rate of interest; and,
6. a 347 day year (i.e., a 5% shop margin) for cars dedicated to single-car and 3 to 10 car shipments, and a 329 day year (i.e., a 10% shop margin) for cars dedicated to multiple-car shipments of at least 50 cars.

Based on the capital recovery factor, the per diem ownership cost--excluding car maintenance--is calculated by the following formula:

$$\text{per diem A.E.C.} = \frac{P\left(\frac{i(1+i)^n}{(1+i)^n - 1}\right) - S\left(\frac{i}{(1+i)^n - 1}\right)}{d}$$

where A.E.C. = annual equivalent cost;

P = purchasing price;

S = salvage value;

i = interest rate;

n = number of years; and,

d = number days per year.

Under the above assumptions, it follows that for box and hopper cars dedicated to single-car and 3 to 10 car service,

$$\frac{(\$16{,}500)\ (0.11746) - (\$2{,}000)\ (0.01746)}{347} = \$5.48464$$

* The service lives of cars assumed in this study represent the best available judgement of actual economic car life under typical operating conditions. It is recognized that service life will vary under different operating conditions.

and

$$\frac{(\$18{,}500)\ (0.11746) - (\$2{,}500)\ (0.01746)}{347} = \$6.13648;$$

and for hopper cars dedicated to multiple-car shipments of at least 50 cars,

$$\frac{(\$18{,}500)\ (0.13147) - (\$2{,}500)\ (0.03147)}{329} = \$7.15356.$$

No allowance was made for tax credits. Thus, these costs are not directly comparable with leasing costs. Adding the annual tax on a per diem basis yields \$6.03464, \$6.68648, and \$7.70356, respectively. Finally, total car maintenance costs assumed in this study are:

	cost per mile		
	truck	body	total
single-car and 3 to 10 car			1.8
random train	1.25	0.25	1.5
scheduled train	1.20	0.20	1.4

The following table summarizes the single-car turnaround times assumed from the Fort Dodge area to nine destinations:

Estimated Turnaround Times from the Fort Dodge Area to Selected Destinations in Number of Days for Single Car Shipments

Destination	Days
Des Moines	6.75
Cedar Rapids	8.50
Chicago	11.00
Pekin	11.00
Milwaukee	12.00
Kansas City	9.00
Omaha	7.75
St. Louis	10.25
New Orleans	25.00

Source: Railroad companies operating in the Fort Dodge area.

These are representative turns, based upon responses of the four relevant railroads.

Item 18. Treatment of switching costs--interchange. Territorial costs for interchange switching service have been included in ICC Scale Table 3 as a line-haul cost; no interchange switching cost is incurred for "local" traffic, that is, traffic handled by a single railroad. Since the study had access to the actual route from each origin to each destination, territorial interchange switching cost was deducted for local movements, and was retained for interline movements.

Item 20. Percent empty return of equipment.
The Interstate Commerce Commission in April of 1962 commenced proceedings with the purpose of determining "whether the approval and adoption of certain cost formulas would result in general improvement of the quality of cost evidence presented in formal proceedings . . .". One of the principal findings issued July of 1970 is the following: there is "no single method of apportioning joint or common costs found universally acceptable, and any method of apportionment utilized for ratemaking purposes should be required to be designed to reasonably reflect the specific circumstances attending the transportation performed". Therefore, subsequent to July 1970, it is valid to adjust the empty return ratio between the origin and destination under consideration when determining the actual cost of transportation between those two points.

The ICC Scale employs territorial empty return ratios ranging from 0.48 to 0.52 for general service unequipped box cars, and from 1.03 and 1.08 for covered hopper cars. Since the tonnage moving to the study area in box cars is comprised basically of sack feed and sack fertilizer, and is limited to a greater extent than reflected in these territorial averages, the present study assumes the box ratio to be 0.80; similarly, the hopper car ratio is assumed to be 1.00.

Item 23. Adjustment for platform costs.
Table 3 of the ICC Scale includes an average terminal cost for platform handling of carload traffic moving in box cars. Since grain does not require such a service, this cost is deducted.

Item 24. Adjustment for floating equipment costs.
Territorial costs for floating service at terminal harbors or in line-haul service are included in the ICC Scale in the respective terminal and line-haul costs. Since the particular movements under consideration by this study did not involve such traffic, this cost is deducted.

Multiple-car adjustments

The multiple-car shipments analyzed include the following: shipments ranging in size from 3 to 10 cars, 50 cars, 80 cars, and 115 cars. The analysis makes the following basic assumptions: 1) a "full train" is defined, here, to be a group of cars of sufficient number so as to move from origin to destination and back as a through train. The number of cars required to qualify as such a dedicated unit varies among railroads depending upon available power and the track profile; it is assumed that 50 cars is the minimum number satisfying this definition; 2) in the case of 3 to 10 car consignments, at least 50 cars originate on the same day and are assembled into a unit to be delivered to more than one site at a grain market. All of the empty cars are picked up and returned as a unit to the origin locations. Thus, the 3 to 10 shipment size satisfies the definition of a full train; 3) both the 3 to 10 and 50 car trains are "random" trains, subject to the demand of the shipper; 4) the 80 and 115 car trains are "scheduled" trains, in the sense that they operate continuously, making round trips to a destination and returning to the Fort Dodge area on a year-round basis.

To summarize, all four sizes of multiple-car shipments are considered to be through trains, such that the 3 to 10 and 50 car cases move at random, while the 80 and 115 car cases are scheduled. The multiple-car adjustments are now considered. The assumptions and adjustments to multiple-car shipments were based on detailed discussions with railroad executives and cost analysts.

Item 12. Type of train.

Appendix E of the ICC Scale exhibits territorial averages by type of train with respect to differences in weight of the trailing tons, the number of locomotive units, and wages of train and engine crew. In the present study, the trailing ton weight of the four multiple-car cases were adjusted to be consistent with the single-car box and hopper car tonnages (Item 11) and tare weights (Item 14). Based upon these total trailing weights, the estimation of the number of locomotive units required for each multiple-car case is consistent with Appendix E territorial averages.

With respect to crews' wages, the territorial averages were retained for random trains; whereas, it is assumed that the equipment utilization characterized by scheduled trains will generate a 6% reduction in the wage cost incurred by random trains, through cost savings associated with crew costs and fringe benefits.

Item 16. Treatment of switching costs--origin or destination. The territorial variable cost per carload for switching at either the point of origin or destination includes locomotive expenses, fuel, crews, and track maintenance related to switching. The number of per car switching minutes required to perform a switching maneuver generally decreases as the number of cars in the cut increases; this study assumes that the per carload origin or destination switching cost for random units of at least 50 cars is 25 percent lower than that of single-car cuts.

Units of labor and equipment allocated to this switching operation are characterized by some amount of non-productive time. To the extent that an increasing proportion of traffic is handled by scheduled rather than random trains, some increase in productivity is likely to result. The present study assumes that the per carload origin or destination switching cost for scheduled trains is 55 percent lower than that of single-car traffic.

Item 17. Treatment of origin or destination portion of freight-train car costs.
The following table summarizes the single- and multiple-car turnaround times assumed from the Fort Dodge area to nine destinations by size of shipment:

Estimated Turnaround Times from the
Fort Dodge Area to Selected Destinations
by Type of Rail Shipment in Number of Days

Destination	single-car	3 to 10 car	50 car	scheduled
Des Moines	6.75			
Cedar Rapids	8.50			
Chicago	11.00	10.00	5.00	
Pekin	11.00	10.00	5.00	
Milwaukee	12.00	11.00	6.00	
Kansas City	9.00			
Omaha	7.75			
St. Louis	10.25			
New Orleans	25.00	16.00	11.00	8.00

Source: Railroad companies operating in the Fort Dodge area.

For the 3 to 10 car and 50 car cases, turnaround days were estimated for the export markets and central Illinois, while for the 80 and 115 car cases turnaround was estimated for Chicago and Gulf export only. These are representative turns based upon information supplied by the four railroads and upon estimates of the time required for shipments to perform various activities involved in moving from origins to destinations. Table 52 presents the estimated time required to perform these activities for movements from the Fort Dodge area to the Gulf by size of shipment. For example, a scheduled train is assumed to require one day to load at the origin, two days to move from the origin to the destination, one day to unload at the destination, and two days to return to the origin. An additional two days are included to account for contingencies such as derailments, unexpected congestion and acts of God. This total of eight days from the Fort Dodge area to the Gulf is considered to be reasonably practical for scheduled trains, under the assumptions of this study.

The 50 car train includes one additional day for unloading at the Gulf, and two more days for contengencies to account for the time required to initially gather the empty cars. The train composed of 3 to 10 car shipments includes an additional three days contingency over the 50 car shipment size to account for inefficiencies involved in the multiple-origin and multiple-destination pattern assumed for this type of shipment. Moreover, two more days are included for the process of assembling and dissembling cars at the multiple-origin and destination sites. As in the case of the adjustment to Item 17 for single-car traffic, ownership cost based upon turnaround time was substituted for the territorial variable cost of the ICC Scale.

Item 19. Treatment of switching costs--intertrain and intratrain.
Territorial costs for intertrain and intratrain switching service performed in making up and breaking up trains at intermediate train yards are included in Table 3 of the ICC Scale as a line-haul cost. Since a full train once assembled does not require such service, this cost was deducted for all multiple-car shipments considered in this study.

Item 22. Station clerical costs.
Terminal variable station clerical expenses per shipment at origin and destination include the wages and salaries of employees engaged in the following activities:

Table 52.

Estimated Turnaround Times from the Fort Dodge Area to the Gulf by Type of Activity and Rail Shipment in Number of Days.

Activity	Scheduled 115-Car train	50-Car	3 to 10-Car
load	1	1	1
unload	1	2	2
transit	4	4	4
contingency	2	4	7
assemble full cars at origin			0.5
disassemble full cars at destination			0.5
assemble empty cars at destination			0.5
disassemble empty cars at origin			0.5
Total	8	11	16.0

auditing, preparation of waybills, accounting, billing, and others which occur in general offices. The present study assumes that all demand-incident service, regardless of consignment size, requires nearly the same clerical capacity as the single-car capacity reflected in the ICC Scale. Therefore, it was assumed that random trains generate a per carload reduction of $1.50 in clerical cost. On the other hand, scheduled trains are assumed to generate a 55 percent reduction of the territorial clerical costs.

Capacity utilization

There is a basic cost associated with running a railroad; this cost has been called "train running capacity" and is incurred by purchasing the units of labor and equipment required to run the railroad. To the extent that shippers are willing to abandon random transportation demands generated by grain market pressure and adjust to a continuously scheduled transportation pattern, train running capacity is able to be utilized with increased efficiency. Thus, a railroad is able to increase traffic density markedly on a particular stretch of track over which moves a high proportion of scheduled and a low proportion of random traffic.

Under the assumption that 50 to 60 percent of the grain moving from the Fort Dodge area is shipped via scheduled trains, the present analysis assumes a reduction in capacity cost of one-sixth over randomly scheduled traffic.

Adjustment of 1969 costs to reflect wage-price level changes

The ICC Scale is based upon 1969 rail operating costs, and does not contain adjustments reflecting wage and price level changes for subsequent years. There are no published railroad cost indices which incorporate all railroad costs. A cost index based on wage rates, fringe benefits and all materials is published by the Association of American Railroads. Since in this AAR index wages and fringe benefit costs have increased more rapidly than other costs during the period 1969-1972 the heavy weighting of the wages and fringe benefits tends to bias the index upward.

An alternative cost index was developed to remove much of this upward bias. The index used is a base period type known as the Laspeyre index. The formula for this index is:

$$L_{o1} = \frac{\sum_i P_{1i} Q_{oi}}{\sum_i P_{oi} Q_{oi}}$$

where P_o = base period price level;

P_1 = price level in the year under consideration;

Q_o = base period quantities;

and i is an index of commodities. By definition this index holds the quantity of inputs constant over the two years.

In constructing this revised index, it was assumed that the cost of inputs other than wages, fringe benefits, and non-fuel materials and supplies increased at the same rate as fuel. This study applies the index to estimate the 1969-72 change in railroad costs; to minimize bias from changes in the input mix, 1971 was selected as the base year. Data for constructing the index were obtained from the 1973 Yearbook of Railroad Facts. Using this procedure, the estimated change in the railroad cost level from 1969 to 1972 is 24.5 percent; the interpretation of this number is as follows: if a railroad purchased the 1970 mix of inputs in 1972, it would incur a 24.5 percent cost increase relative to 1969.

Appendix G

HIGHWAY DATA PREPARED FOR
USE IN A GRAIN
TRANSPORTATION STUDY

Prepared by: Iowa State Highway Commission
Planning and Programming Department
Needs Study Unit

February 16, 1973

Appendix G

Increased Highway Construction and Maintenance Cost Determination

The basic assumption underlying the cost determinations described herein is that construction costs and maintenance costs for road surface and structures vary directly with the number of axle loadings of a certain magnitude that it sustains. Therefore, the first step is to express all truck loads being used in terms of the equivalent 18,000 pound (18 kip) axle loadings that the road would sustain through one pass by each truck.

The equivalent 18 kip loadings and other factors used in the following calculations were taken from tables developed by the American Association of State Highway Officials (AASHO) from the results of extensive road tests conducted by the Association in 1960 and 1961. The AASHO tables used are Tables 54 through 56 The purpose of each table will be described at the appropriate point in the following discussion.

Construction costs

It is assumed that the increased highway construction cost resulting from the railroad abandonments would be based on the cost of resurfacing a road segment after it has deteriorated from new or like new condition to the point of needing resurfacing.

The measure of pavement condition used is the pavement serviceability index (psi). This is a surface roughness index which can range from 5.0 downward to 0.0 with the upper limit being the indication of the best condition possible.

Tables 54 and 55 show the remaining 18 kip load applications a pavement can be expected to sustain before a resurface is needed at psi of 2.0. Therefore, if the pavement was assumed to be new at 4.5 psi and needing resurfacing at 2.0, then the values in Tables 54 and 55 can be used as the total number of 18 kip loads the pavement can sustain before it needs resurfacing.

The columns in Tables 54 and 55 headed DT are the pavement structure indicators which determine the number of loads a road can withstand. DT stands for "Design Term" and is an indicator of the effective thickness of surface, base and subbase on a road. The procedures for its determination can be found in: American Association of State Highway Officials - Committee on Highway Transport - August 1962.

Manual of instructions for pavement evaluation survey

By dividing the equivalent 18 kip axle loading of a particular type of truck into the maximum number the surface can sustain, the number of passes the pavement would theoretically last before needing resurfacing can be calculated. This quotient then divided into the cost of replacing the surface yields a theoretical cost figure which represents the cost of one pass by each truck.

The following example is provided for clarification.

Given: DT - 10.5 Interstate Rigid Pavement

36 Ton Truck

Step A - Using the axle loadings shown in Figure 28, Table 56 yields the number of 18 kip equivalent loads each truck will add to the pavement.

0.03 + 1.12 + 1.12 = 2.27 eighteen kip loads per truck

Step B - Determine the total number of kip loads the road can withstand before needing a resurfacing - from Table 54 DT = 10.5, so from Table 54 the maximum number of kip loads the road will withstand is 23,523,000.

Step C - Determine increased construction cost per truck pass

$$\text{Increased Cost} = \frac{\$33{,}000^{*}\ (\text{Cost/Mile})}{\dfrac{23{,}523{,}000\ (\text{Max. 18 kip loads remaining})}{2.27\ (\text{Equivalent 18 kip loads/truck})}}$$

$$= \$\ 0.00319/\text{Truck-Mile}$$

Maintenance costs

It is assumed that the increased maintenance costs resulting from the railroad abandonments would vary directly with the number of axle loadings of a certain magnitude that the road surface sustains. The only costs being considered here are those associated with road surface and structure maintenance.

The total average maintenance cost is the total cost for maintenance on a given road type from that time when the road was new or like new to the point of needing resurfacing, and is determined by multiplying the average surface life in years by the current yearly average maintenance cost. The total average maintenance costs being experienced on various road types is shown in Table 57. These maintenance costs are cross-referenced to the DT in Table 53 MC, for the various types of pavements used.

Calculations for increased maintenance cost are similar to those for increased construction cost.

Given: DT = 10.5 Interstate Rigid Pavement

36 Ton Truck

Step A - Equivalent 18 kip = 2.27 as in construction cost example.

Step B - Total 18 kip loads is 23,523,000 for DT = 10.5 Rigid

Step C - Increased Maintenance Cost

$$= \frac{\$13{,}802.00 \text{ (Total Cost/Mile)}}{\dfrac{23{,}523{,}000 \text{ (Max. 18 kip loads remaining)}}{2.27 \text{ (Equivalent 18 kip loads/truck)}}}$$

= $0.00133/Truck-Mile

Table 53 CC.

Increased Highway Construction Cost per Truck per Pass.

Pavement Type	DT	Remaining 18-kip loads	Two-Lane* resurf Cost/mi.	Construction cost per truck mile 4-ton 18k-0.0102	14-ton 18k-0.3620	27-ton 18k-0.6700	21-ton 18k-2.0100	36-ton 18k-2.2700
Interstate rigid	10.5	23,523,000	33,000.00	$0.00001	0.00051	0.00094	0.00282	0.00319
Other primary rigid	9.5	11,363,000	33,000.00	0.00003	0.00105	0.00195	0.00584	0.00659
High flexible	5.5	3,758,000	33,000.00	0.00009	0.00318	0.00588	0.01765	0.01993
Intermediate flex.	4.5	651,000	33,000.00	0.00052	0.01835	0.03396	0.10189	0.11507
Surface treated flex.	3.0	18,000	3,000.00	0.00170	0.06033	0.11167	0.33500	0.37833
Secondary unpaved **	--	-------	-------	0.00000	0.00000	0.00000	0.00000	0.00000

* Developed for 1971-1990 Iowa Highway Needs Study. For DT values of 3.0 this figure becomes $3,000 per mile for seal coating.

** Data obtained by telephone interview with Kirby Lidman, Iowa State Highway Commission.

Table 53 MC.

Increased Highway Maintenance Cost per Truck per Pass.

Pavement Type	DT	Remaining 18-kip loads	Surface life total mainten. cost/mile	Maintenance cost per truck mile 4-ton 18k-0.0102	14-ton 18k-0.3620	27-ton 18k-0.6700	21-ton 18k-2.0100	36-ton 18k-2.2700
Interstate rigid	10.5	23,523,000	13,802.00	$0.00001	0.00021	0.00039	0.00118	0.00133
Other primary rigid	9.5	11,363,000	5,843.60	0.00001	0.00019	0.00034	0.00103	0.00117
High flexible	5.5	3,758,000	3,795.22	0.00001	0.00037	0.00068	0.00203	0.00229
Intermediate flex.	4.5	651,000	4,028.64	0.00006	0.00224	0.00415	0.01244	0.01405
Surface treated flex.	3.0	18,000	9,560.00	0.00542	0.19226	0.35584	1.06753	1.20562
Secondary unpaved *	--	-------	-------	0.02100	0.02100	0.02100	0.02100	0.02100

* Data obtained by telephone interview with Kirby Lidman, Iowa State Highway Commission.

Table 54.

Rigid Pavement*
Remaining 18 Kip Applications Before Resurfacing Will Be Required.
(At PSI = 2.0)

(In thousands)

DT	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					Pavements in very-good condition (p = 4.5)					
6.	-	-	-	-	-	780	868	964	1,069	1,184
7.	1,309	1,445	1,592	1,753	1,927	2,116	2,322	2,544	2,785	3,046
8.	3,327	3,632	3,961	4,316	4,700	5,112	5,558	6,035	6,549	7,102
9.	7,695	8,331	9,016	9,743	10,529	11,363	12,260	13,219	14,236	15,332
10.	16,489	17,730	19,046	20,450	21,943	23,523	25,212	26,996	28,900	30,917
11.	33,045	35,310	37,714	40,244	42,914	45,751	48,753	51,928	55,259	58,790
12.	62,503	66,435	70,550	74,920	79,488	84,333	89,392	94,733	100,369	106,243
13.	112,460	118,932	125,777	132,954	140,475	148,320	156,603	165,272	174,341	183,823

*Source: American Association of State Highway Officials Committee on Transport - August 1962 Manual of Instructions for Pavement Evaluation Survey.

Table 55.

Flexible Pavement*
Remaining 18 Kip Application Before Resurfacing Will Be Required.
(At PSI = 2.0)

(Figures in parentheses are units; all others in thousands)

DT	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					Pavements in very-good condition (p = 4.2)					
2.	(416)	(656)	(1,012)	(1,530)	(2,271)	(3,315)	(4,763)	(6,746)	(9,428)	(13,309)
3.	18	24	32	42	55	71	92	117	148	189
4.	233	289	357	438	535	651	788	950	1,141	1,366
5.	1,629	1,937	2,294	2,712	3,196	3,758	4,406	5,154	6,014	7,003
6.	8,137	9,434	10,914	12,601	14,522	16,705	19,177	21,979	25,147	28,717
7.	32,745	37,264	42,346	48,037	54,424	61,555	69,515	78,406	88,280	99,293
8.	111,486	125,017	140,043	156,675	175,009	195,285	217,631	242,220	269,296	299,082

*Source: American Association of State Highway Officials Committee on Transport - August 1962 Manual of Instructions for Pavement Evaluation Survey.

Table 56.

Equivalent 18 Kip Single Axle Load Application Factors
for Varying Single and Tandem Axle Loads.
(Based on AASHO Road Test Equations)

Single Axles		Tandem Axles	
Load (kip)	Factor	Load (kip)	Factor
2	.0002	4	.0004
3	.0008	6	.0014
4	.002	8	.004
5	.005	10	.01
6	.01	12	.02
7	.02	14	.04
8	.03	16	.06
10	.08	18	.10
12	.18	20	.15
14	.34	22	.23
16	.60	24	.33
18	1.00	26	.46
20	1.57	28	.64
22	2.37	30	.85
24	3.45	32	1.12
26	4.88	34	1.45
28	6.78	36	1.85
30	9.09	38	2.33
32	12.05	40	2.90
34	15.72	42	3.57
36	20.23	44	4.35
38	25.70	46	5.26
40	32.29	48	6.31

Source: American Association of State Highway Officials - Committee on Highway Transport - August 1962 - Manual of Instructions for Pavement Evaluation Survey.

Table 57.

Maintenance Costs for Road Surfaces and Structures.

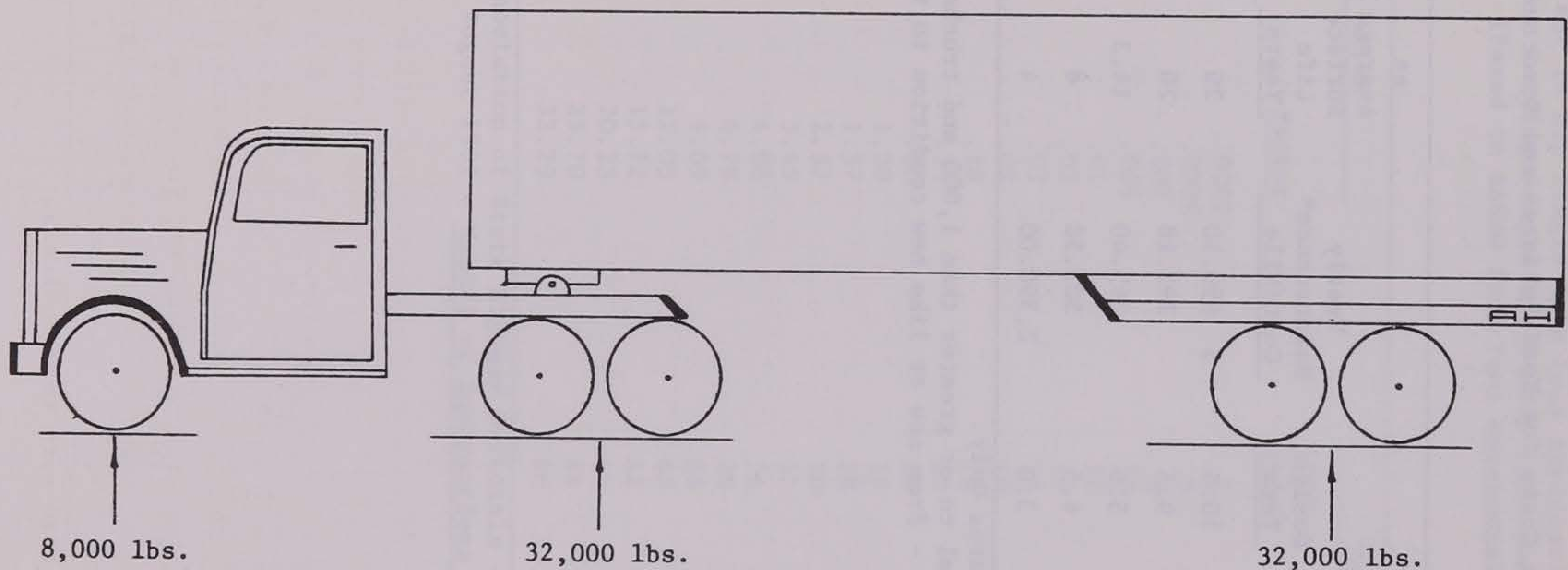
Road Pavement Type	Design Term	Yearly Maintenance* Cost/Mile	** Average Surface Life Years	Surface Life Total Maintenance Cost/Mile
Interstate Rigid	10.5	$ 690.10	20	$13,802.00
Other Primary Rigid	9.5	292.18	20	5,843.60
High Flexible	5.5	265.40	14.3	3,795.22
Intermediate Flexible	4.5	503.58	8	4,028.64
Surface Treated Flexible	3.0	2,390.00	4	9,560.00

* For Surface and Structures Only.

** Based on Total ADT equal to or greater than 1,000 and trucks greater than 5 percent. Surface Life - from new or like new condition to the point of needing resurfacing.

Figure 28.

36.0 Ton 3-Axle Tractor with Tandem Axle Trailer.



18 k Equivalent = 0.0300 + 1.1200 + 1.200 = 2.2700

Appendix H

Budgeted Country Elevator Operations without a Railroad

I. Basic Assumptions

A. Revenue

1. Grain Volume -- the elevator will be filled with grain at harvest time. No additional grain will be received during the rest of the year.
2. Corn Margins -- the elevator will pay the farmer the same price for corn that subterminals will pay.
3. Soybean Margins -- all the soybeans will be trucked to local processors. Typically, local processor's bids are less than bids by out-of-state processors or exporters. On this basis, it is assumed that soybean margins will be reduced to 3¢ per bushel from 6.8¢ per bushel in 1971.
4. There will be no change from 1971 grain drying revenues.
5. Approximately 30% of the corn receipts will be available for hedging during the harvest season. The following data summarize the expected per bushel hedging revenue on 165,000 bushels of hedged corn:

Basis improvement (5 year average)	16¢
Less: interest costs (8% annual rate for 7 months on $1.05 corn)	4.9¢
Shrink	1.5¢
Insurance	.5¢
Net gain per bushel	9.1¢

6. Approximately 40% of the soybean receipts will be available for hedging during the harvest season. Lifting of soybean hedges and sales of soybeans to local processors will be made in an equal volume each month throughout the year. Thus harvest-time hedges will be held for a maximum of 3 months. A portion of the beans purchased from farmers during the spring will be hedged and stored into the summer, but storage costs on these beans will exceed hedging returns.

Dr. Robert N. Wisner assisted with this analysis.

Table 58 shows the time-pattern of soybean purchases, as well as monthly carrying costs, hedging revenues and profits. Hedging profits during the fall will be partially offset by losses during the summer, resulting in net hedging returns of about $1,900 on soybeans.

7. A gain of one cent per bushel on corn and two cents per bushel on 75% of the soybeans will be realized from reduced physical losses by shipping by truck rather than box car.
8. Revenue from farmer stored grain will be as follows:

Corn:	385,000 bushels for 4 months @ 5.5 per bushel	$21,175
Soybeans:	138,000 bushels for 7 months @ 8.5 per bushel	11,730
	Total	$32,905

9. Revenue from government grain storage is $1,000.
10. There will be no change from 1971 feed or fertilizer revenues.

B. Expenses

1. Additional trucking costs on 75% of the soybeans (that proportion now shipped by rail) will be 3 cents per bushel.
2. The subterminal buying the corn will either pay the trucking costs from the elevator to the subterminal or will offer a premium on price just sufficient to cover corn trucking costs.
3. Dry fertilizer costs will increase $2.50 per ton to cover trucking costs.
4. There will be no change from 1971 grain drying costs or feed costs.
5. There will be a $2,500 reduction in labor cost because of reduced cost from loading grain in trucks rather than box cars.
6. There will be additional interest expense on $35,000 fertilizer inventories for 4 months at 8% interest totaling $933 per year.

II. Results

A. Based on these assumptions and on the 1971 actual operating results, Table 59 shows budgeted revenues and expenses without a railroad compared with the actual 1971 revenues and expenses with rail shipping available. Net revenue is budgeted at $19,816 per year, compared with actual net revenue of $20,024 in 1971.

Table 58.

Budgeted Country Elevator Soybean Hedging Operations without a Railroad.

Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Farmer Sales Pattern (% of beans sold monthly)	⟵	40	⟶	0	0	8.6	8.6	25.6	8.6	8.6	0	0
Gross Hedging Returns	0	0	5¢	9.5¢	11.5¢	0	0	0	0	4¢	4¢	2¢
Carrying cost/bu. ($3/bu., 8% interest)	0	0	2¢	4¢	6¢	0	0	0	0	4¢	6¢	4¢
Net returns/bu.	0	0	3¢	5.5¢	5.5¢	0	0	0	0	0	-2¢	-2¢
Volume sold by elevator	19,500 bu./mo.											
Total hedging net returns	0	0	$585	$1,073	$1,073	0	0	0	0	0	-$390	-$390
Total net hedging returns from soybeans		$1,951										

Table 59.

Budgeted Elevator Operating Statement without a Railroad Compared with 1971 Actual Results with a Railroad.

	Budgeted Operating Statement without a Railroad					
	Grain	Feed	Fertilizer	Other	Total	1971 Actual Operating Statement
Sales Volume						
Corn	550,000 bu.	2100 tons	dry 2800 tons			
Soybeans	230,000 bu.		NH_3 450 tons			
Handling Margins						
Corn	$	$	$	$	$	$
Soybeans	6,900					
Total	6,900	31,100	45,000	6,800	89,800	98,483
Service Income						
Storage	33,900				33,900	32,600
Drying	8,200				8,200	8,200
Cleaning	2,000				2,000	2,000
Reduced Losses from Trucking Grain	11,000				11,000	
Hedging Revenue Corn	15,000				15,000	
Soybeans	1,900				1,900	
Other		10,000	2,000	8,000	20,000	27,287
Total Gross Income	78,900	41,100	47,000	14,800	181,800	168,570
Expenses						
Extra Storage			1,000		1,000	
Hauling	12,200		7,100		19,300	3,048
Depreciation	15,681	4,480	9,600	2,242	32,003	32,003
Other Expenses	46,709	37,420	31,100	9,258	124,487	125,562
Total	74,590	41,900	48,800	11,500	176,790	160,613
Net Earnings from Operation	4,310	-800	-1,800	3,300	5,010	7,952
Patronage Refunds	5,750	4,881	3,147	1,028	14,806	12,072
Total Earnings	$10,060	$ 4,081	$ 1,347	$ 4,328	$19,816	$20,024

B. Comparison of present value if the elevator is liquidated versus continuing in operation at the budgeted income level for the next eight years.

1. Liquidation of the assets and payment of liabilities would yield the following results:

Assets:		
Current assets	$263,000	
Rolling stock and movable equipment	50,000	
Sale of building and land at market price	35,000	
Discounted present value of deferred refunds from regionals	22,500	
Present value of assets		$370,500
Existing Liabilities:		
Current liabilities	$128,000	
Long term debt	40,000	
Deferred refunds to members	116,000	
Common stock	20,000	
Total liabilities		$304,000
Present value of liquidation, discounted at 8% interest		$ 66,500

2. Value if the elevator remains in business:

Present value of $19,816 annual income stream at the end of eight years discounted at 8% interest.	$113,882

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