



Rail based grain distribution systems in the Golden Triangle Area of Montana
by Linda Joan Cox

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Applied Economics
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Abstract:

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The results of the analysis indicated the 50-car system with a large percentage of the grain assembled at subterminals had the lowest total cost. It was concluded that distribution systems for the region with multiple-car rail shipments incorporated for moving grain to market had a cost advantage.

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Date

June 1, 1978

RAIL BASED GRAIN DISTRIBUTION SYSTEMS IN
THE GOLDEN TRIANGLE AREA OF MONTANA

by

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A thesis submitted in partial fulfillment
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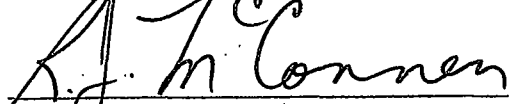
in

Applied Economics

Approved:



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ABSTRACT

This research analyzes alternative rail based grain distribution systems in the Golden Triangle Area. The objective was to determine the distribution system which minimized the cost of marketing the grain sale for this major grain producing area in Montana.

A multi-stage transshipment model was developed which estimated the total cost and the optimal grain shipment patterns for rail based distribution systems. The sizes of the rail shipments included in the various systems were single-, 10-, 25-car, and 50-car.

The results of the analysis indicated the 50-car system with a large percentage of the grain assembled at subterminals had the lowest total cost. It was concluded that distribution systems for the region with multiple-car rail shipments incorporated for moving grain to market had a cost advantage.

Chapter 1

INTRODUCTION

Montana produced 156 million bushels of wheat and 51 million bushels of barley in 1975; placing Montana fourth for wheat production and third for barley production in the United States. In 1974-75, 92 percent of the wheat and 74 percent of the barley grown in Montana was shipped to West Coast markets in Portland and Seattle. Since most of Montana's grain markets are on the West Coast, transporting this grain over 700 miles to market is costly. Before the August 1976, rail rate increase, the transportation cost from Great Falls to the West Coast accounted for 19 percent of the farm value for wheat and 24 percent of the farm value for barley. (17) Any effort to keep this marketing cost down will be an important step toward keeping Montana farm incomes up.

The feasible methods used for shipping Montana grain to market are rail, truck, and truck-barge. In 1970-71 about 30 percent of the wheat shipped out of Montana was moved by truck. This figure dropped to 16 percent in 1972-73, resulting from rail rate reductions which made trucking grain relatively less attractive. In 1971-72 over half of the barley marketed out of state was moved by truck while in 1973-74 this figure dropped to 22 percent. Thus, less grain is shipped by truck and rail transportation is occupying a more important place in

the Montana grain industry. (17)

A multiple-car rail system has a cost advantage over a single-car rail system. (7) Montana has a single-car rail system. In some states a multiple-car rail system has been introduced with grain elevators paying a lower multiple-car rate if a specified number of cars are shipped in one day.

Due to insufficient storage and loading capabilities, most grain elevators in Montana would be unable to take advantage of multiple-car rates. Investment to upgrade facilities must occur before elevators can take advantage of multiple-car rates. As the grain loading facility gets larger, economies of scale occur and marketing costs decrease. However, the larger the facility the larger the investment cost becomes. The optimal balance between increasing investment costs and decreasing marketing costs would be valuable information as multiple-car grain loading facilities are constructed.

Objective

The objective of this study was to determine the optimal grain distribution system which minimized the cost of marketing grain produced in a major grain producing area in Montana. The grain marketing system for the selected region is described in terms of:

- a. The number, location, and capacity of subterminal elevators in the area.

- b. The final destination of the region's grain.
- c. The transportation network serving the region, including rail, water, and highways, in terms of shipper access points, terminal locations, lines and routes, and amount of grain carried in each vehicle type and mode.

The last section of this chapter deals with previous research in agricultural marketing systems. The method of analysis used in this research is presented in Chapter 2. Chapter 3 describes the procedures used in collecting the data and estimating the cost functions used in the model. The results of the study are in Chapter 4 with a summary and conclusions in Chapter 5.

Previous Research

This analysis of alternative grain transportation systems has been completed in other states but not in Montana. The most widely known and detailed study of this type is "An Economic Analysis of Alternative Grain Transportation Systems: A Case Study" done at Iowa State University. That study

presents the results of research conducted to determine which grain transportation system would yield highest net income in a 6 1/2-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 subterminals would be required to load the shipments of 50 cars or more. Also, alternative rail line options were considered. . . . Total

investment requirements were estimated for selected grain distributing systems. The evaluated alternatives were ranked in terms of total joint net income, investment requirements. (2)

Other studies dealing with grain transportation systems which relied heavily on the method of analysis used in this Iowa State University study were completed for Missouri (27), Indiana (10), and Nebraska (1). All previous cited studies found multiple-car rail systems had a cost advantage over single-car rail systems.

The research was partially based on the techniques used in the Iowa State University study. However, this research differs since the optimal grain transportation system was selected on the basis of minimum total cost. This eliminated the need for future grain prices in the model. Also, the scope of this research was limited. No alternative rail line options were considered and the points of origin for the grain transportation system were country elevators. Since country elevators located in the same towns were assumed not to cooperate with each other, new grain-loading facilities called subterminals were required to load multiple-car shipments of 25 and 50 cars.

Two alternative methods of analysis have been developed which incorporate 0,1 integers to represent subterminals. The first approach is Network Programming and was developed at Texas A & M University (8); the second, developed at Purdue University (10), uses Bender's

Decomposition to solve the mixed integer problem. Before these two techniques were developed, mixed integers in a subterminal location problem would have made a solution costly and time consuming.

Chapter 2

METHODOLOGY

The first part of this Chapter describes the structure of the model used in this research while the mathematical model is presented in the second part.

Description of Model

The method of analysis used in this research is based on a transshipment plant location model. (3) This model determines the optimal size, number, and location of grain handling plants for a ten county area in Montana under alternative rail-based grain distribution systems. The objective function minimized all the transportation, handling, and facility investment costs for moving a specified amount of grain from elevators to final markets under the constraints of partial equilibrium in the grain industry. (2)

The alternative transportation patterns for grain considered in this research were from country elevators to various final markets through subterminals or from country elevators directly to final markets. The modes of transportation available for this grain movement were rail, truck, and truck-barge. All costs associated with grain movement were incorporated into the model. A visual representation of the model is shown in Figure 2-1.

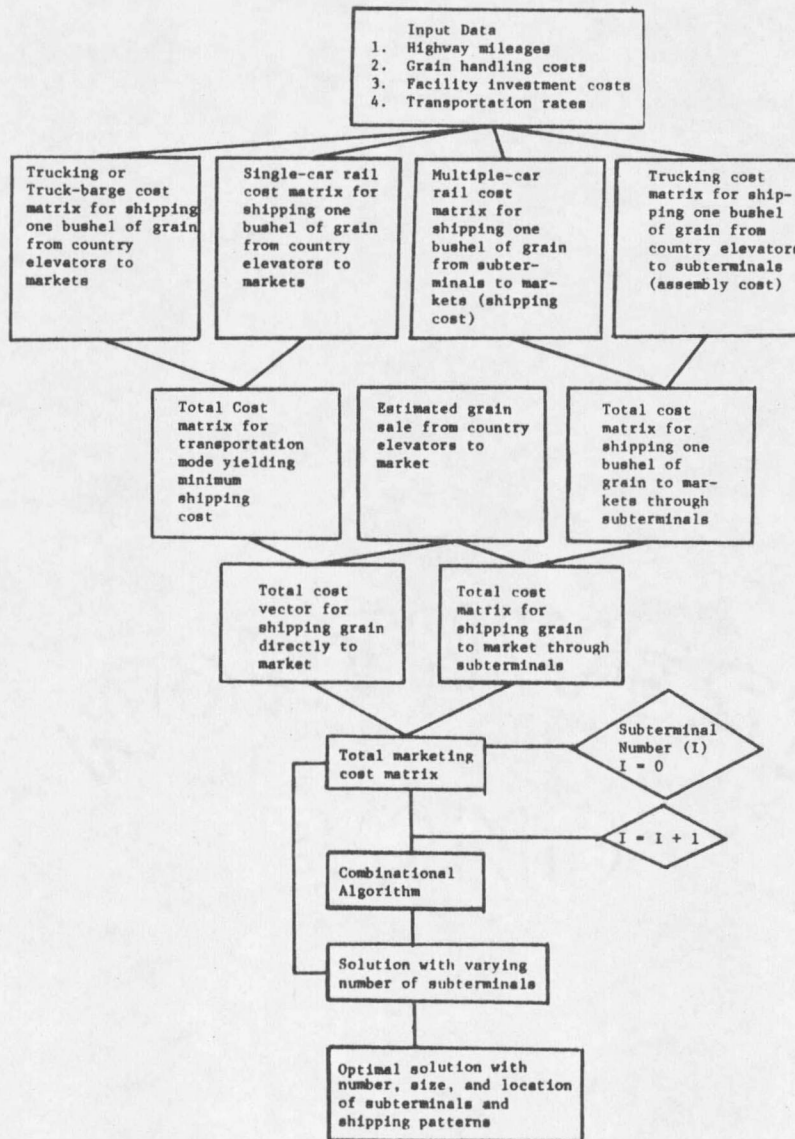


Figure 2.1. Schematic Flow of the Analysis Surrounding the Linear Programming Model.

The selection of the optimal grain distribution system was based on a cost comparison. The total marketing costs for the alternative systems including all combinations of numbers and locations for subterminals were estimated. The number of subterminals ranged from one to twelve, with the optimal system having the lowest total marketing cost.

The cost for transporting grain from country elevators to market included the transportation cost for shipping grain and the grain handling cost at country elevators. The costs for transporting grain from country elevators to market through subterminals were the cost of shipping grain from country elevators to subterminals, the grain handling cost at country elevators, the shipping cost for moving grain from subterminals to market, the grain handling cost at subterminals, and the subterminal investment costs. Subterminals had lower handling costs than country elevators and could obtain lower multiple-car rail rates for shipping grain to market. In some cases, this may mean that shipping grain from country elevators directly to market costs more than shipping grain from country elevators to market through subterminals.

This study area contained 56 grain shipping origins which have one or more country elevators. The shipping origins are shown in Figure 2-2.

Commercial grain sales for 1990 from shipping origins included wheat and barley. The oats produced in the region were assumed to be sold locally. This study examines one time period extending from July 1 to June 30.

Shipping Origins and Markets

The study area was a ten county region in northcentral Montana. This region included the following counties: Toole, Pondera, Teton, Chouteau, Cascade, Judith Basin, Fergus, Blaine, Hill, and Liberty. This region is a major grain producing area in Montana and will be referred to as the Golden Triangle Area. In 1975, these ten counties produced 50 percent of the grain grown in Montana. The time horizon over which this comparison of grain distribution system extends was up to 1990.

The three final markets for Montana grain are Seattle, Portland, and Minneapolis. Seattle and Portland are export or domestic markets while Minneapolis represents a domestic market.

Grain Transportation Activities

Country elevators could ship grain to subterminals by truck or to final markets by single-car rail shipment or truck-barge. Subterminals could ship grain to final markets by multiple-car rail shipment, truck, or truck-barge. Country elevators could not take advantage of multiple-car rail shipments because inadequate facilities

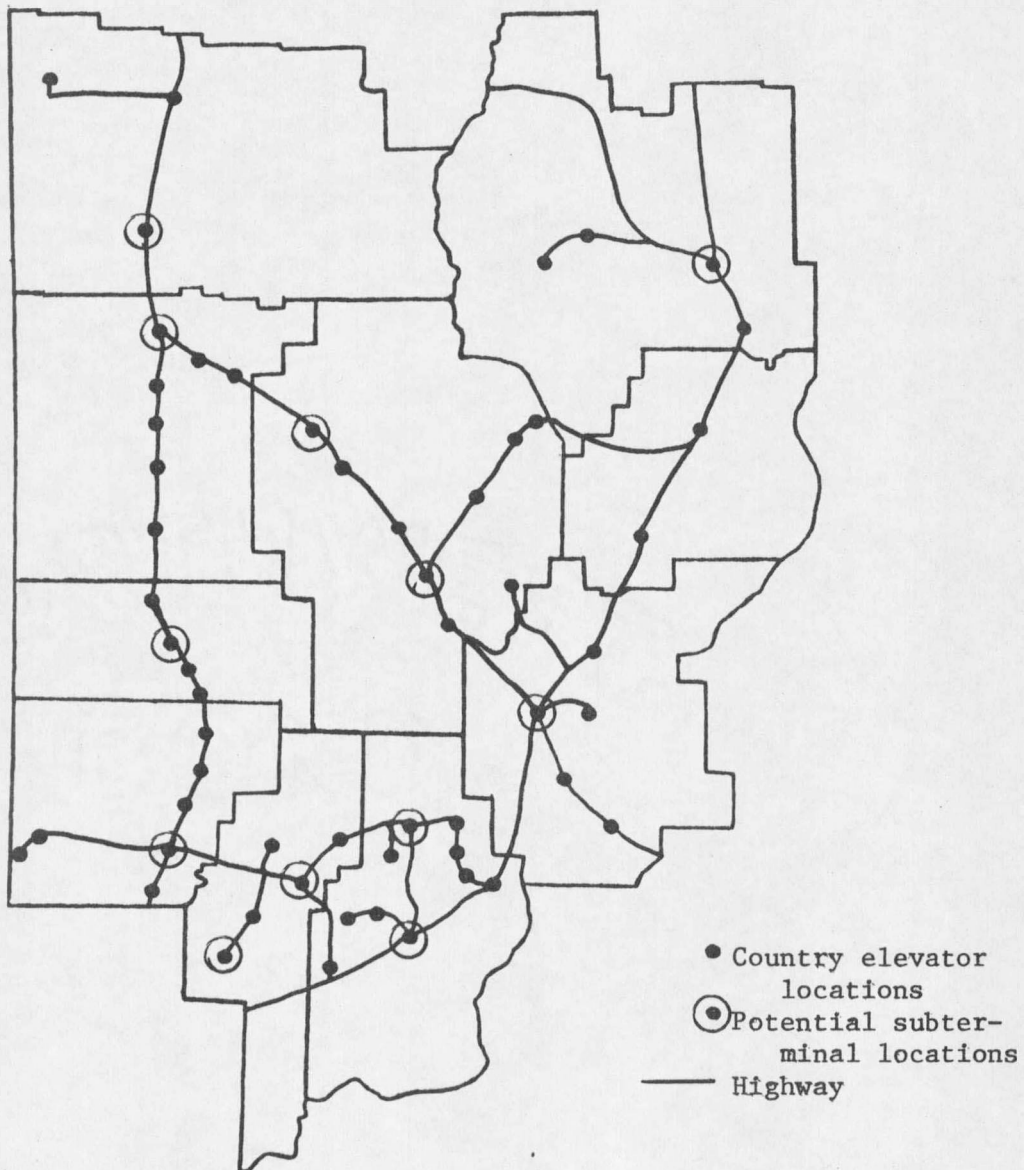


Figure 2.2. Location of the highway system, country elevators, and potential subterminals, Golden Triangle Area, 1976.

rendered them incapable of handling in one day the large amounts of grain moved with multiple-car shipments. Thus, the three alternative routes for grain transportation from a point of origin to a final market were assumed as follows:

1. Country elevator to final market using truck, truck-barge or single car rail shipment.
2. Country elevator to subterminal using truck shipment, then subterminal to final market using truck-barge or multiple car rail shipment.
3. Subterminal to final market using truck-barge or multiple car shipment.

There were no published rates for shipping grain by truck in the area. Thus, a model for a tractor-semi-trailer operation which can haul 850 bushels in one load was used in estimating the cost per mile for trucking wheat and barley. The location of the highway system, country elevators, and potential subterminals for the Golden Triangle Area is presented in Figure 2-2.

The Burlington-Northern and the Chicago, Milwaukee, St. Paul, and Pacific Railroad (known as the Milwaukee) handle grain shipped out of the Golden Triangle Area by rail. The location of the rail line system with country elevator and potential subterminal locations indicated is shown in Figure 2-3.

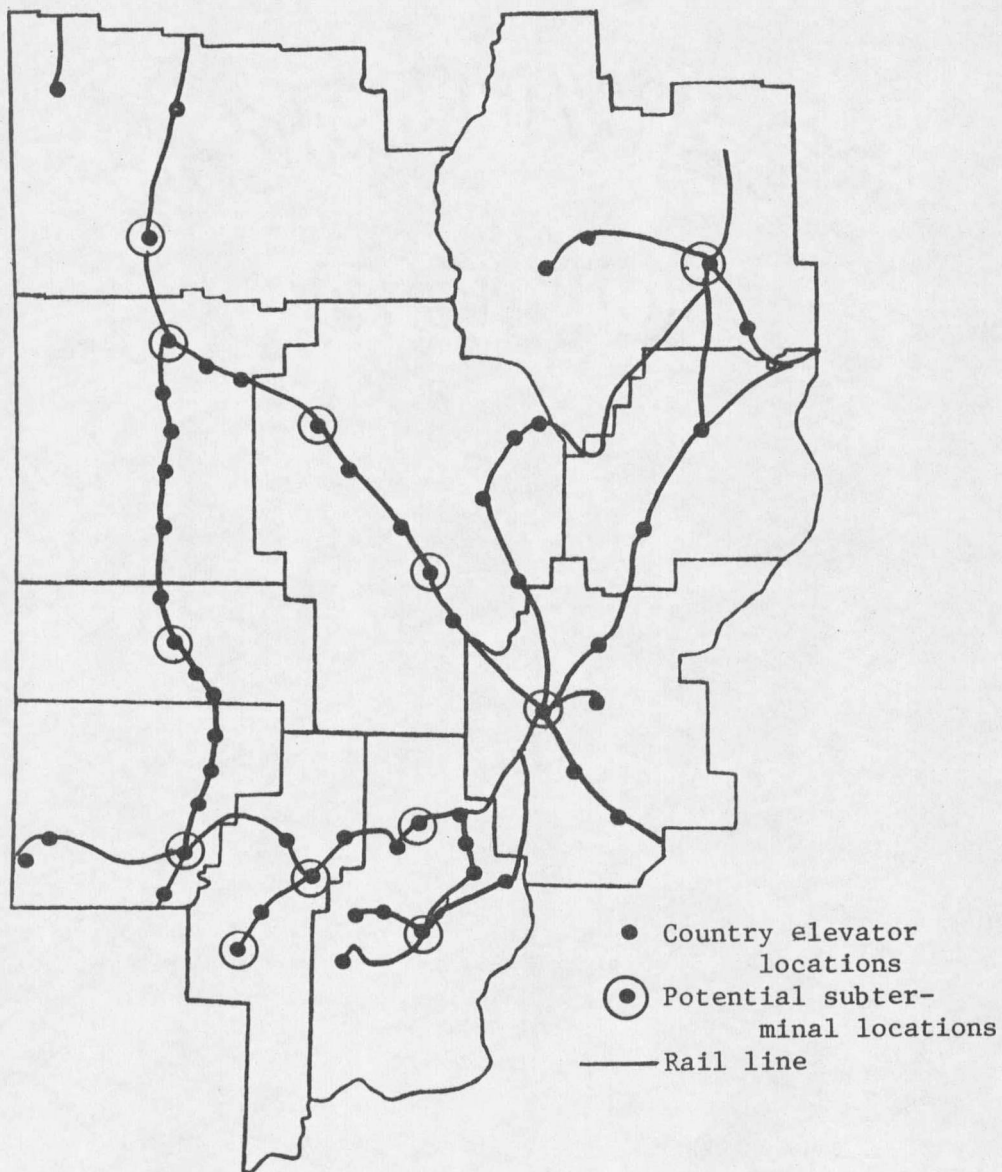


Figure 2.3 Location of the rail line system, country elevator, and potential subterminals, Golden Triangle Area, 1976.

Single-car rail rates were available, but multiple-car rates were estimated. The variable rail costs were basically extrapolated from railroad cost scales published by the Interstate Commerce Commission. Variable rail costs rather than fully allocated costs were used because variable costs are more commonly used as a cost criteria for rail car operation than fully allocated cost. If each individual haul does not cover its variable cost, it should not be undertaken. A ratio of single-car rate to the single-car cost was used to derive multiple-car rates from multiple-car costs. The procedure used in these computations is presented in Chapter 3.

The alternative sizes of multiple-car shipments analyzed in this study are 10-car, 25-car, and 50-car. The multiple car shipments can be divided into three different types, depending upon the agreement between the shipper and the railroad. They are full train, random shipment, and scheduled train. A full train is defined as a group of cars of sufficient number to move from the origin to the destination and back as a through train. It was assumed 50 cars is the minimum number satisfying this definition. A random shipment is one which is scheduled at the discretion of the shipper. A scheduled train is defined as one which operates continuously, making round trips to a destination on a year round basis. This study assumed a 50-car shipment can be a full train or random shipment while 10-car and 25-car shipments are random shipments.

The water access points in the truck-barge system along the Columbia-Snake River System are Lewiston, Idaho; Central Ferry, and Pasco, Washington. Trucks move grain to these water access points, then grain is shipped by barge to port elevators in Longview, Kalama, Vancouver, and Portland. The barges are operated by Tidewater, Krappton, Shaver, and Columbia Marine Lines. There are rail lines to Lewiston and to the area around Pasco making rail-barge shipment possible. However, in 1976, no grain was moved in this manner. (17)

There were no published barge rates for shipping grain. The rates used in the model were estimated based on a barge measuring 242' x 42' x 16 1/2'. The methodology used in estimating barge transportation cost is presented in Chapter 3.

Handling and Investment Cost

The cost associated with moving grain through an elevator is divided into two parts; 1) the total annual cost of building or enlarging an elevator; and 2) the variable handling costs of receiving, storing, and loading out grain at elevators. The variable handling costs differ for country elevators versus those for sub-terminal elevators. The costs associated with receiving and loading out grain vary with the mode of transportation used for shipping. (2)

Country elevators require a certain minimum capacity of

facilities to perform the functions of a country elevator. However, subterminals require a greater minimum capacity of facilities than country elevators require. Since subterminals can receive grain from farmers and country elevators to load multiple-car trains, subterminals require greater receiving, storage and load-out capacity. Thus, because of these minimum capacity requirements of elevators and the indivisibilities of construction, total elevator expansion or construction costs vary by elevator size. (2)

Country elevators existing at the beginning of the planning horizon may stay in use or may be expanded into subterminals while some new subterminals may be constructed. Before any elevator can expand or additional facilities can be constructed, the storage facilities of existing elevators must be used to capacity. This accounts for: 1) the sunk cost of existing facilities that affect the actual cost of expansion; and, 2) the preference of some producers to deal with local elevators. Thus, expansion and/or construction costs vary with the location and size of existing facilities. (2)

A description of the facilities at the beginning of the planning horizon, 1976, was necessary to determine the additional investment required to implement the various marketing systems. The methods and procedures used in determining handling and investment costs are presented in Chapter 3.

The Mathematical Model

The objective of the model, expressed algebraically, is to find grain distribution system which will minimize cost:

$$(2-1) \quad Z = \sum_i (C_{mij}^k + H_{mi}) X_{ij}^k$$

or, with the addition of subterminals,

$$Z = \sum_i (C_{mij}^k + H_{mi}) X_{ij}^k + \sum_i (C_{min}^k + H_{mi}) Y_{in}^k + \sum_n (C_{mnj}^k + H_{mn}) Z_{nj}^k + \sum_n I_n$$

where:

i = Index of elevator locations ($i = 1, 2, \dots, 56$)

n = Index of subterminal locations ($n = 1, 2, \dots, 12$)

j = Index of final markets ($j = 1, 2, 3$)

k = Index of grains ($k = 1, 2$)

m = Index of transportation mode ($m = 1, 2, \dots, 6$)

C = Transportation cost

H = Grain handling cost

I = Subterminal investment cost

X = Quantity of grain shipped from elevators directly to market

Y = Quantity of grain shipped from elevators to subterminals

Z = Quantity of grain shipped from subterminals to market.

However, equation (2-1) is minimized subject to some material balance equations and prerequisite conditions for elevator capacity expansion. These equations and conditions are as follows:

1. All commodity flows over space and time are non-negative.

$$(2-2) \quad x_{ij}^k, x_{in}^k, x_{nj}^k \geq 0$$

2. Total grain receipts at a final market equal the grain shipped to that market from country elevators and subterminals.

$$(2-3) \quad x_{\cdot j}^k = \sum_i x_{ij}^k + \sum_n x_{nj}^k$$

3. The grain shipped from a subterminal to a final market equals total grain receipts at a subterminal from country elevators plus total grain receipts from farmers at a subterminal.

$$(2-4) \quad x_{nj}^k = x_{\cdot i}^k + \sum_i x_{in}^k$$

4. The grain shipped from a country elevator to a subterminal equals total grain received from farmers at a country elevator minus the grain shipped from a country elevator to a final market.

$$(2-5) \quad x_{in}^k = x_{\cdot i}^k - x_{ij}^k$$

5. Total outshipments from a country elevator equal total grain receipts from farmers at a country elevator.

$$(2-6) \quad X_{ij}^k + X_{in}^k = X_{.i}^k$$

The cost comparison used as a decision rule in this computational algorithm is between the costs in the following expressions.

$$(2-7) \quad (C_{mij}^k + H_{mi})$$

$$(2-8) \quad (C_{min}^k + H_{mi}) + I_n + (C_{mnj}^k + H_{mn})$$

If expression (2-7) is greater than expression (2-8), then a country elevator should ship grain directly to a final market. If expression (2-7) is less than expression (2-8), then a country elevator should ship grain through a subterminal to a final market.

The Limitations of the Model

The biggest limitation of this model is the exclusion of the farm sector. The use of the farm as a point of origin for grain movement would yield more accurate results for the selection of an optimal grain distribution system. There is some movement of grain directly from the farm to final markets in the Golden Triangle Area. However, the inclusion of the farm sector would result in a problem too large to handle in a study of this size and scope.

Another limitation is introduced with the assumption that the country elevators located in a potential subterminal location will not cooperate with each other. There seemed to be competition between the elevators in a location which supports this assumption.

Only one elevator in each location will expand or build a new facility to take advantage of a multiple-car rate. If their existing capacities are not large enough to enable them to also take advantage of a multiple-car rate, the other elevators at that location will eventually be driven out of business.

The estimation of transportation costs, handling costs, investment costs, and commercial grain sales have some obvious limitations associated with them. Even if all the data used in making these estimates was completely correct, they still remain only estimates.

Chapter 3

DATA COLLECTION

This chapter describes the procedures used in collecting the data and estimating the cost functions used in the transshipment plant-location model.

Commercial Grain Sale

The surplus grain available for sale in the ten counties in the Golden Triangle Area in 1990 was estimated using the following equation (3-1):

$$(3-1) \quad GS_i = GP_{i(t-1)} - [(OS_i + CS_i) - \sum_{j=1}^6 (L_j)(FR_j)(LP_{ji})] - SR_i$$

where

GS_i = grain sold from county i (time t)

GP_i = grain production for county i (time t-1)

OS_i = oats available for livestock in county i

CS_i = corn available for livestock in county i

SR_i = seed requirement for county i

L_i = classes of livestock

1 = hogs

4 = dairy cows

2 = chickens

5 = cattle on feed

3 = beef cows

6 = sheep

FR_i = feed requirements per animal per year

LP_{ji} = jth livestock number requiring feed in county i

The data necessary for these county grain sale projections came from the Montana Agricultural Statistics and from livestock and soil specialists at Montana State University. For further information on these county grain sale projections, refer to the study by Won W. Koo and Linda Cox. (15)

Grain sales by county were allocated to the elevator locations within the county on the basis of relative storage capacity. Wheat and barley sales allocated to each elevator location are shown in Appendix A.

The upper bound placed on wheat and barley sales for 1990 from each elevator location was twice the quantity of wheat or barley sold from that elevator location in 1974-75. The lower bound was one-half the quantity of wheat or barley sold from that elevator location in 1974-75. These upper and lower bounds were necessary because some of the grain sold from each county will not be handled by an elevator; a farmer may market his grain himself rather than using local elevator services. Due to the large size and scope of farms in the northern part of the Golden Triangle Area, the farmers located there are more likely to market their grain themselves.

Grain Transportation Cost

The transportation costs for shipping grain by truck, barge, and

rail are developed in this section.

Trucking Cost

The three cost components in this 850 bushel, tractor-semi-trailer trucking cost model are: 1) fixed costs; 2) variable cost; and, 3) transfer costs. The information used in estimating trucking cost was obtained from interviews with three trucking firms in Montana.

(26) (37) (38) The following equation (3-2) gives the various costs involved in the fixed cost component.

$$(3-2) \quad FC = AEC + L + I + A + R$$

where:

FC = fixed cost per year

AEC = annual equivalent cost for interest expenses and depreciation

L = license fee and highway use taxes per year

I = insurance expenses per year

A = administrative costs per year

R = maintenance and repair expenses per year

Equation (3-3) shows the costs associated with the variable cost component.

$$(3-3) \quad VC = F + O + T + W$$

where:

VC = variable cost per mile

F = fuel cost per mile

O = oil and oil filter cost per mile

T = tire cost per mile

W = driver's wage rate per mile

The total cost of operating a semi-truck for a year, including all three cost components is shown in equation (3-4).

$$(3-4) \quad TC = (VC \times M) + FC + TR$$

where:

TC = total cost per year

M = mileage per year

TR = transfer cost per year

The assumptions made in estimating fixed cost are as follows:

1. The purchase price for a tractor is \$38,000 and for a trailer \$14,000. The life expectancy of the tractor is 5 years and of the trailer is 7 years. The salvage value for both pieces is 20 percent of the purchase price.
2. A 10 percent interest rate is assumed on borrowed capital.
3. The annual equivalent cost is computed using the following equation (3-5):

$$(3-5) \quad AEC = P \left[\frac{i(1+i)^n}{(1+i)^n - 1} \right] - S \left[\frac{i}{(1+i)^n - 1} \right]$$

where:

AEC = annual equivalent cost

P = purchase price

S = salvage value

n = life expectancy

i = interest rate

4. The license fee and highway use tax per year is \$1870.
5. Insurance costs vary with the level of coverage. In this analysis, the annual insurance payment for collision and liability is \$1500.
6. Administrative costs are \$500 per year.
7. Annual maintenance and repair costs are 5 percent of the purchase price of the tractor and 2 percent of the purchase price of the trailer.

Total fixed cost per year under these assumptions is \$17,140.

The assumptions necessary for computing variable cost are as follows:

1. Fuel consumption is estimated at 4.0 miles per gallon with diesel fuel priced at 55 cents per gallon. Oil and oil filters are changed every 10,000 miles, costing \$70. One gallon of oil is needed every 1,000 miles at \$1.70 per gallon.
2. Eighteen tires at \$170 each are needed every 100,000 miles.
3. The driver's wage rate is 14 cents per mile.

Total variable cost per mile is 31.71 cents per mile.

The total transfer cost for one truck is \$3.89 per trip if the

trip distance is less than 350 miles. It is \$4.38 if the trip is greater than 350 miles.

Two cost components of average trucking cost per mile will vary depending on the distance of the haul. Thus, average cost per mile becomes a function of mileage. The estimated cost of hauling grain by truck for a variety of round trip distances are shown in Table 3-1.

Total trucking cost is calculated using the following equation

(3-6):

$$(3-6) \quad TC_{ij}^k = M_{ij} C^k G_{ij}^k$$

where:

TC_{ij}^k = total trucking cost from point of origin i to destination j for grain k

M_{ij} = mileage from point of origin i to destination j

C^k = trucking cost per cwt per mile for grain k

G_{ij}^k = quantity of grain k trucked from point of origin i to destination j

Rail Cost

Single-car rail rates were obtained from the Montana Wheat Research and Marketing Committee. (21) (23) The rail costs were basically extrapolated from "Rail Carload Cost Scales, 1973" published in Interstate Commerce Commission Statement No. ICI-73. (33) (34)

Table 3-1

Estimated Costs of Hauling Grain in Tractor-Trailer by Trip Distance
And Speed Using 1976 Cost Levels

Round Trip Distance	No. of Trips per Year	Annual Mileage	Fixed Cost/ Year	Variable Cost/Mile	Transfer Cost	Total Cost Per Year	Average Cost Per Mile
100	705	70508	17410	.3171	2749	42517.09	.6030
150	495	74285	17410	.3171	1931	42896.77	.5775
200	382	76330	17410	.3171	1490	43104.24	.5647
250	310	77612	17410	.3171	1209	43229.77	.5570
300	262	78492	17410	.3171	1022	43321.81	.5519
350	253	88481	17410	.3171	1108	46575.33	.5264
400	223	89090	17410	.3171	977	46637.44	.5235
500	180	89957	17410	.3171	788	46723.36	.5194
600	150	90544	17410	.3171	657	46778.50	.5166
700	130	90968	17410	.3171	569	46824.95	.5147
800	114	91289	17410	.3171	499	46856.74	.5133

It will be referred to as the "ICC Scale". The variable costs in the ICC Scale include 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 road property and 100 percent of the equipment used in freight service. These ICC Scales provide costs per cwt by railroad territory, type of car, short-line distance, and load weight.

Covered hopper cars were selected as the type of car used to haul the grain. The rail costs for wheat are lower than those for barley due to the density difference between the two. The rail costs to each final market from each elevator location will vary because of the difference in rail mileages between each elevator location and final market. The railroad territories selected were the Western Trunk and the Mountain Pacific as shown in Figure 3-1. Further information on these rail cost estimations can be obtained in "An Economic Analysis of Single-Car and Multiple-Car Rail Costs of Transporting Montana Grain in Mountain Pacific Region", a study done by Won W. Koo and Thomas P. Drinka. (16)

The single-car rail costs were estimated for each elevator location, type of grain, and final market and 10-car, 25-car and 50-car rail costs were estimated for each potential subterminal location, type of grain, and final market. The smaller rail cost

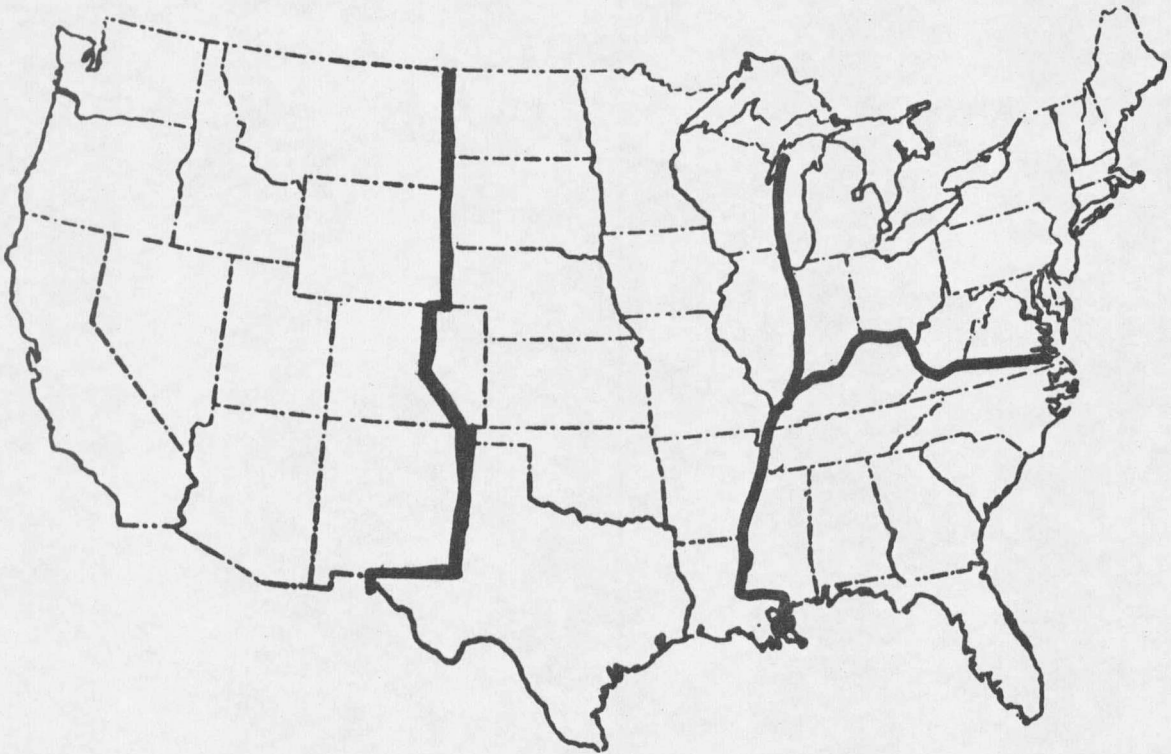


Figure 3-1. The Delineation of Regions used in Study of Rail Costs in Grain Distribution Systems.

savings with 10-car and 25-car shipments is due to the fact that 10-car and 25-car shipments are not large enough to become a full train which does not require switching at intermediate yards. A 50-car shipment is large enough to be a full train and consequently has a much quicker turn around time than 10-car and 25-car shipments have. If a 50-car shipment is considered a scheduled train, it is possible to reduce the estimated 50-car rail cost even more. The differences between the estimated single car, 10-car, and 50-car rail costs are shown in Figure 3-2.

A ratio of the single car cost to the single car rate was calculated. This ratio was used in conjunction with the 10-car, 25-car, and 50-car costs to determine a 10-car, 25-car, and 50-car rail rate, respectively. The single car, 10-car, 25-car, and 50-car rail rates used in this study can be found in Appendix B.

The total rail transportation cost for shipping grain is estimated by the following equation (3-7):

where:

RC_{ij}^k = total rail cost of shipping grain k from point of origin i to destination j

C_{ij}^k = rail rate for shipping grain k from point of origin i to destination j

G_{ij}^k = quantity of grain k shipped from point of origin i to destination j

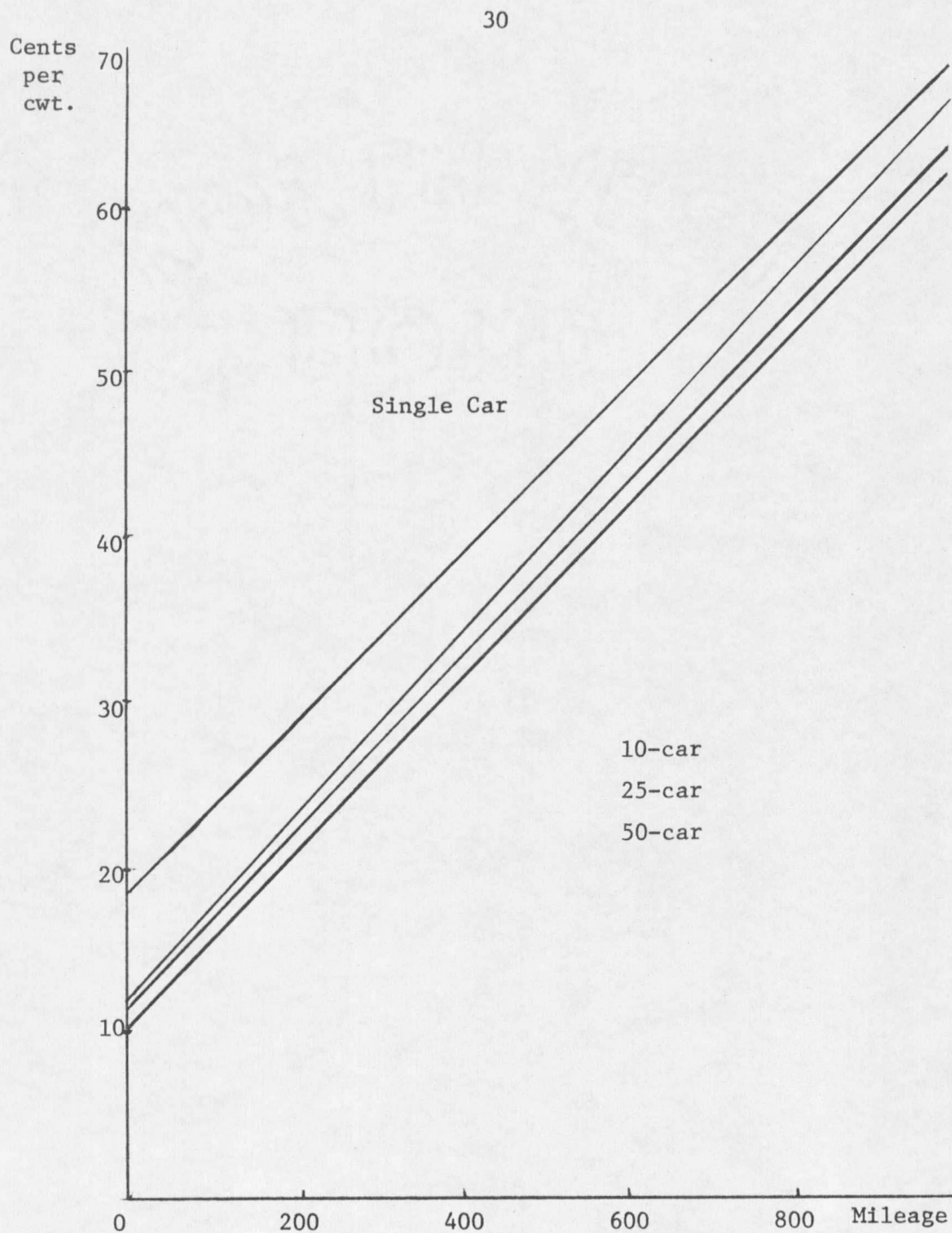


Figure 3-2. Estimated Single-car, 10-, 25-car and 50-car Rail Costs from Montana Origins to the West Coast.

Barge Cost

Barge cost is divided into three categories: 1) investment cost; 2) operating cost; and, 3) towing cost. The information used in determining barge costs was obtained from C.A. Sylnstad of Tidewater Barge Lines. (31) The investment cost is the cost of owning the barge and depends on the kind of barge used. The assumptions made in estimating investment cost are as follows:

1. The purchase price of a barge measuring 242' x 42' x 16 1/2' which can hold 2700 tons of grain is \$750,000. The life expectancy of the barge is 25 years and its salvage value at the end of this time is \$37,500.
2. A 10 percent interest rate is assumed on borrowed capital.
3. The investment cost is the annual equivalent cost. It is computed using equation (3-5).

Operating cost includes insurance expense, maintenance and repair costs, administration expense, and taxes. The assumptions made in estimating the operating cost for grain transportation by waterways are as follows:

1. The insurance expense on the barge is .75 percent of the value of the load and on the cargo is 2 percent of the cargo freight rate. The insurance expense for the barge is \$5,625 per year and for the cargo is \$2,240 per year.
2. The maintenance and repair costs are 4 percent of the

straight line depreciation per year. The maintenance and repair costs are \$28,500 per year.

3. The administration expense necessary to operate a barge is \$600 per year.
4. The taxes for the barge are \$8,375 per year.
5. There are assumed to be 300 working days in the year.

The total estimated operating cost for a barge on the Columbia-Snake River System is \$150.80 per day.

The towing cost is the cost of the tugboat facilities used to move the barge from one water access point to another. It depends on the distance of the trip. The assumptions made in calculating the towing cost from the water access points to Portland are as follows:

1. The charge for custom tug towing is \$87 per hour on the Snake River and \$141 per hour on the Columbia River. The speed of the tow is 8 miles per hour upstream or downstream.
2. The distance of the trip from Pasco to Portland is 237 miles. The distance of the trip from Central Ferry to Portland is 319 miles. The distance of the trip from Lewiston to Portland is 374 miles.

The total estimated towing cost for the trip from Pasco to Portland is \$2,103.40. The total towing cost for the trip from Central Ferry to Portland is \$2,995.10. The total towing cost for the trip from

Lewiston to Portland is \$3,593.20.

Since the total operating and investment cost for a barge on the Columbia-Snake River System is \$425.02 per day, the total operating and investment cost per trip depends on the days required to make the trip from each water access point to Portland. The days required for the trip from Pasco to Portland is 6 days, making the total cost for this trip \$4,045.60 or \$1.60 per ton. The 6.5 days required for the trip from Central Ferry to Portland make the total cost for transporting grain by barge \$5,757.70 per trip or \$2.09 per ton. The trip from Lewiston to Portland requires 7 days, incurring a total cost of \$6,568.30. for the trip or \$2.39 per ton of grain. Costs do not vary with the type of grain shipped.

The transportation cost for shipping grain by barge in the Columbia-Snake River System are estimated using the following equation (3-8):

$$(3-8) \quad TC_{ij} = C_{ij} G_{ij}$$

where:

TC_{ij} = total cost of shipping grain by barge from water access point i to destination j

C_{ij} = cost per ton of shipping grain by barge from water access point i to destination j

G_{ij} = quantity of grain shipped from water access point i to destination j

Handling Cost

The handling cost for a country elevator and a subterminal was obtained from "Cost of Storing and Handling Grain in Commercial Elevators, Projections for 1974/75", an Economic Research Service publication. (32) The weighted average book and replacement costs per bushel for storing and handling grain for various types of elevators was given in this publication. The weighted average book and replacement costs rather than standardized book costs were used since

"Average book costs more nearly represent the actual expected expenditures an elevator operator will incur, and average replacement costs reflect the expenses associated with a new elevator entering the industry."
(32)

The total variable cost per bushel for a country facility and an inland terminal vary depending on the mode of transportation used for the receiving and the loadout of the grain. The 1974/75 costs were updated to 1976 using the consumer price index for 1976. The grain handling cost for country elevators and subterminals is shown in Table 3-2.

Investment Cost

A description of the existing facilities at each potential subterminal location was obtained from an interview with each elevator manager. The criterion for these elevator descriptions includes

Table 3-2

Estimated 1976 Variable Grain Handling Costs in Cents
Per Bushel for Country Elevators and Subterminals,
Adjusted from 1974/75 Figures

County Elevator Total Variable Cost Per Bushel in Cents

Received by Truck	2.281
Loadout by Truck	2.505
Loadout by Rail	2.730

Subterminal Total Variable Cost Per Bushel in Cents

Received by Truck	1.744
Loadout by Truck	1.304
Loadout by Rail	1.908

$CPI_{74} = 147.7$

$CPI_{76} = 170.14$

storage capacity, the ability to expand storage capacity, loadout capacity, track capacity, and the ability to expand track capacity. A minimum storage capacity and minimum loadout capacity per day of 33,000 bushels and enough track for ten covered hopper cars are the requirements necessary before an elevator can load ten cars in one day to obtain a 10-car rail rate. A minimum storage capacity and minimum loadout capacity per day of 82,500 bushels and track for loading 25 cars are the requirements an elevator must meet to obtain the 25-car rail rate. The requirements necessary to obtain the 50-car rail rate are a minimum storage capacity and minimum loadout capacity per day of 165,000 bushels and track for loading 50 cars.

The elevators in each subterminal location were evaluated as to how close each one meet the three groups of requirements. The elevator in each location that fit these requirements the closest, usually the largest elevator, was the one selected to become a subterminal. The expansion needed to bring the selected elevator in each subterminal location up to the three sets of minimum standards was determined. Three different size subterminals are associated with the three alternative multiple-car rail systems and consequently each subterminal location has three different investment costs attached to it depending on the rail system.

The elevators in some potential subterminal locations are located so that there is no room to expand the storage and/or the

track capacity. Since existing facilities are unable to expand, these locations required the construction of a new facility. No new facilities were required with the 10-car rail system, but both the 25-car and the 50-car systems required some new facilities.

The construction costs used in determining the expansion and investment costs for the subterminals were obtained from Rod Jacobson of Jacobson & Son Construction in Bismarck, North Dakota. (12) The estimates for investment cost is based on the following assumptions:

1. A subterminal with a 250,000 bushel capacity is required with a 25-car rail system. A 500,000 bushel subterminal is required with a 50-car system.
2. A 25-car subterminal required 1000 square feet for the scale house and office while the 50-car subterminal required 1200 square feet.
3. The 25-car subterminal was equipped with a belly dumping truck scale and one dump pit. The 50-car subterminal required two belly and end dumping truck scales and two dump pits.
4. Both sizes of subterminals required one protein tester. The 25-car subterminal needed one shipping sampler at \$6,000 while the 50-car subterminal needed two.
5. The legs used for receiving and loadout are rated at 10,000 bushels per hour capacity and cost \$36,000 each.

The smaller subterminal required two legs and the larger required three.

6. The 25-car subterminal needed a double distributor with a capacity of 10,000 bushels per hour. The 50-car subterminal needed a triple distributor at a capacity of 20,000 bushels per hour.
7. Top and bottom conveyers were needed only by the larger subterminal.
8. The requirements for land were four and five acres, respectively, at \$2,500 an acre.
9. The smaller drier was rated at 2,000 bushels per hour and the larger was rated at 3,000 bushels per hour.
10. The cleaners were rated at 2,500 bushels per hour and cost \$25,000 each. The 25-car subterminal needs two and the 50-car subterminal needs three.
11. Sixty feet of rail track are required per rail car. The track costs \$35 per foot for installation and \$12 per foot for subgrading.
12. A 5-car track puller was required by both subterminals to move rail cars.
13. The 25-car subterminal required two 120-pound automatic shipping scales to obtain a 10,000 bushel per hour capacity. The 50-car subterminal required an electronic shipping scale

with a 20,000 bushel per hour capacity.

14. The annual equivalent costs were based on a 10 percent interest rate. No salvage value was assumed for any of the equipment. The annual equivalent costs were calculated using equation (3-5).
15. The annual cost also included the annual insurance and tax cost on the two facilities. Insurance was assumed to be 1.5 percent of the installed cost and property taxes were 12 percent of the installed cost.

The estimated cost of subterminals with these two capacities is shown in Table 3-3.

The cost of constructing any additional storage for the expansion of an existing facility was \$1.50 per bushel. (12) The assumptions used to calculate the cost of installing any additional track for the expansion of an existing facility were the same as those used for the construction of a new facility. The estimated total investment cost and annual equivalent cost for constructing grain loading facilities at the selected potential subterminal sites is shown in Table 3-4.

Table 3-3

Estimated 1976 Installed and Annual Costs of Constructing
Subterminals With Two Rated Capacities

Cost Item	Years for Depreciation	Subterminal With 250,000 bu. capacity	Subterminal with 500,000 bu. capacity
Scale House and Office	20	\$ 30,000	\$ 36,000
Truck Scale	20	80,000	320,000
Sampler and Tester	5	21,000	27,000
Dump Pits	30	17,500	35,000
Legs	10	72,000	108,000
Distributors	10	25,000	35,000
Conveyors	10		30,000
Dust Control Facility	10	60,000	80,000
Aeration & Heat Detection Equip.	10	15,000	20,000
Silos and Tunnel	50	137,500	176,000
Land	--	10,000	12,500
Driers	10	60,000	80,000
Cleaners	10	50,000	75,000
Rail Sliding and Switches	50	141,000	282,000
Car Puller	20	6,000	6,000
Shipping Scale	20	35,000	65,000
Total Installed Cost		\$760,000	\$1,387,500
Annual Equivalent Cost			
5 years		5,539.74	7,122.52
10 years		45,894.09	69,654.86
20 years		17,736.46	50,155.42
30 years		1,856.38	3,712.77
50 years		28,089.23	46,193.42
Annual Insurance and Tax @ 13.5% of Installed Cost		13,380.65	23,873.26
Total Annual Cost		\$112,496.55	\$200,712.25

Table 3-4

Estimated 1976 Total Investment and Annual Capital Recovery Costs of Constructing
Grain Loading Facilities of Three Rated Capacities at Selected Potential
Subterminal Sites, Golden Triangle Area

Location	Size of Multiple Car Shipment					
	10-car		25-car		50-car	
	Total	Annual	Total	Annual	Total	Annual
Big Sandy	0.0	0.0	760,000.00	112,496.55	1,387,500.00	200,712.55
Chester	8,460.00	853.26	760,000.00	112,496.55	1,387,500.00	200,712.55
Chinook	0.00	0.00	760,000.00	112,496.55	1,387,500.00	200,712.55
Choteau	0.00	0.00	0.00	0.00	179,250.00	18,078.98
Conrad	0.00	0.00	16,920.00	1,706.53	77,420.00	7,808.50
Dutton	0.00	0.00	42,300.00	4,266.34	1,387,500.00	200,712.55
Fort Benton	0.00	0.00	760,000.00	112,496.55	1,387,500.00	200,712.55
Great Falls	0.00	0.00	14,100.00	1,422.11	74,600.00	7,524.08
Havre	0.00	0.00	42,300.00	4,266.34	142,300.00	14,352.24
Lewistown	2,820.00	284.42	760,000.00	112,496.55	1,387,500.00	200,712.55
Shelby	0.00	0.00	47,940.00	4,835.18	118,440.00	11,945.74
Valier	0.00	0.00	0.00	0.00	56,400.00	5,688.45

Chapter 4

RESULTS

The grain distribution systems were evaluated by comparing the total marketing cost for shipping the estimated grain sale from shipping origins to domestic and export markets. This chapter describes and evaluates the single-car system and the alternative multiple-car systems using total transportation and investment costs, the optimal mode of transportation, and grain shipping patterns. The last section includes some sensitivity analysis with changes in the shipping and assembly costs of a 50-car system.

1976 Single-Car System

The estimated total marketing cost of shipping 72 million bushels of grain from the Golden Triangle Area to the final markets with the optimal single-car system was \$43,919.648. Figure 4-1 indicates the optimal transportation mode and market for wheat shipped from origins in the Golden Triangle Area. Figure 4-2 presents the optimal transportation mode and market for barley movement from the area. The estimated quantity of grain shipped by transportation mode and market is shown in Table 4-1.

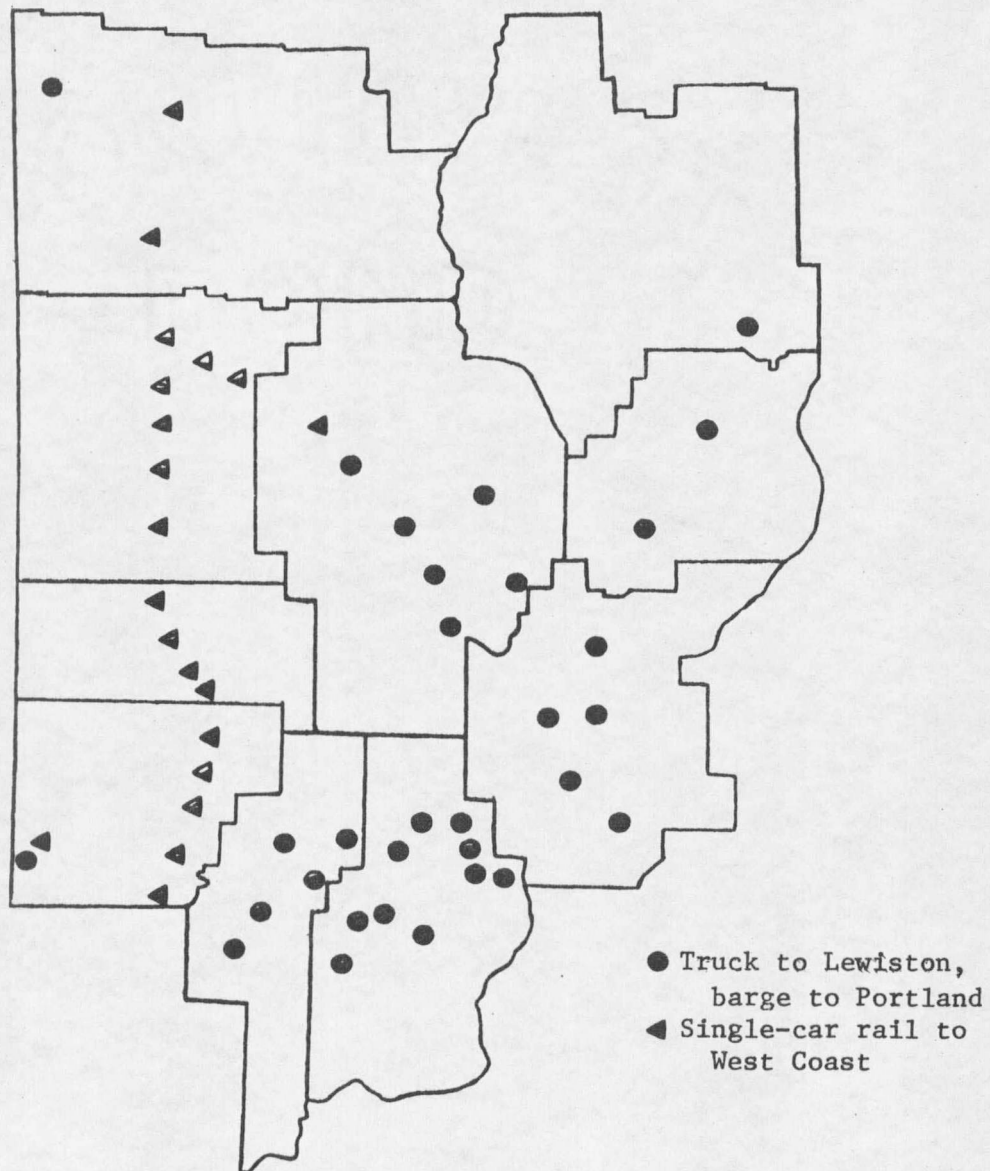


Figure 4-1. Estimated Wheat Flow from Country Elevators to Markets with Transportation Modes for the Single-car Rail System, Golden Triangle Area.

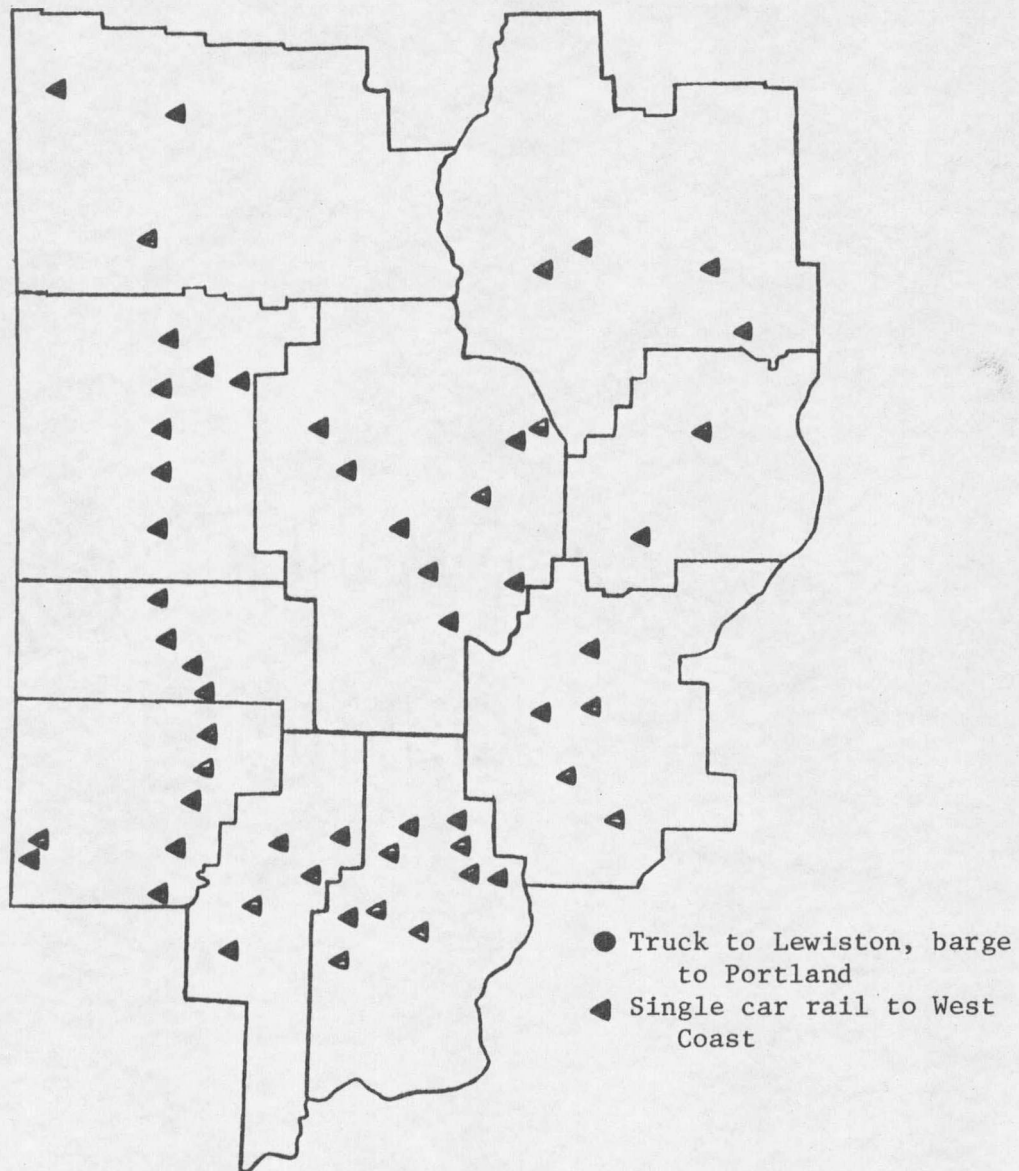


Figure 4-2. Estimated Barley Flow from Country Elevators to Markets with Transportation Modes for the Single-car Rail System, Golden Triangle Area.

Table 4-1

Estimated Grain Shipment from Country Elevators to Markets
For the 1976 Single-Car System

	Quantity of Grain Shipped (1,000 bu)	Percentage of Total Grain Shipped
Single-car Rail Shipment to the West Coast	49,277.3	70
Truck-Barge Ship- ment to the West Coast	21,957.5	30

As shown in Figure 4-1, most shipping origins in the northern region had a cost advantage in shipping wheat by rail. These origins are located on a main rail line making less switching required which keeps rail cost lower. However, elevators on branch lines like those in the southwestern section generally find truck-barge shipment a better alternative.

All truck-barge shipments cost less if grain was trucked to Lewiston and then loaded on barges bound for Portland. This is because the trucking rate per cwt is higher than the barge rate per cwt; making it desirable to truck grain the shortest possible distance. Of the three water access points in the truck-barge system, Lewiston is the closest to the shipping origins in the region.

All barley movement uses single-car shipment to the West Coast.

Single-car rates for wheat and barley are the same ignoring the density difference between the two. However, trucking costs per cwt for barley are higher than for wheat because wheat is denser than barley. If rail rates were adjusted to reflect this weight difference, truck-barge shipment of barley would become competitive with single-car shipment and the optimal barley flow would become identical to the optimal wheat flow.

Alternative Multiple-Car Systems

Some elevators in the area have sufficient loading, unloading and storage facilities for making multiple-car shipments. These locations will have the absolute advantage when competing with the others to obtain subterminals. Consequently, this study allowed these locations to become subterminals. These locations are Havre, Shelby, and Great Falls. Table 4-2 presents the estimated total marketing cost for 10-, 25-car, and 50-car rail systems associated with subterminals ranging in number from four to twelve.

The minimum estimated total cost for each multiple-car system was less than that for the single-car system. The cost decrease varied with a three percent reduction for the 10-car system, a two percent reduction for the 25-car system, and a five percent reduction for the 50-car system.

The optimal number of subterminals for each system was the

Table 4-2

Estimated Total Marketing Costs for the 10-, 25-car, and 50-car
Rail Systems with Subterminal Numbers
Ranging From Four to Twelve

Number of Subterminals	Total Marketing Cost With a 10- Car Rail System	Total Marketing Cost With a 25- Car Rail System	Total Marketing Cost with a 50- Car Rail System
4	43,132,272	43,004,272	41,657,360
5	43,016,464	42,878,848	41,495,920
6	42,904,496	42,776,800	41,361,376
7	42,797,920	42,728,496	41,336,848
8	42,697,328	42,690,992	41,313,392
9	42,636,864	42,681,424	41,300,624
10	42,599,536	*42,673,776	*41,300,448
11	42,572,880	42,705,120	41,382,000
12	*42,567,120	42,778,400	41,535,008
Cost Reduction from Single-car System	1,352,528	1,141,248	2,384,640

*Minimum total cost indicating the optimal number of subterminals.

number associated with the minimum total marketing cost. Each subterminal ships grain to market using multiple-car rail shipments to the West Coast. The subterminal locations and the quantity of grain shipped through the subterminals varied depending on the rail system under examination. Country elevators which ship grain directly to market use the mode of transportation indicated for the single-car system.

The quantity of grain shipped by rail and by truck-barge for each multiple-car system is shown in Table 4-3. As the size of the multiple-car shipment increased from 25 to 50, there was a significant increase in the amount of grain moved by rail. This is due in part to the larger relative rail cost savings with 50-car shipments.

Table 4-3

Estimated Grain Shipment to Market by Transportation
Mode for the Alternative Rail Systems

	10-car System	25-car System	50-car System
Shipped by Rail	62,233.0	60,694.1	67,944.7
Shipped by Truck-Barge	9,001.8	10,540.7	3,290.1

10-Car Rail System

In general, the inverse relationship between transportation and investment costs as a function of subterminal number restricts the number of subterminals placed in the multiple-car rail systems. However, due to relatively low investment costs, the 10-car rail system has all twelve potential subterminals in operation. With little or no upgrading, elevators at all subterminal locations could receive the cost advantage of 10-car shipments.

The optimal flow of grain from country elevators to subterminals

is shown in Figure 4-3. As shown, subterminals in the northern section have expanded marketing areas since it became economically feasible to truck grain from nearby elevators to subterminals for shipment to market. However, the reduced rail rate does not result in many shipping pattern changes for elevators in the southwest with most origins there shipping directly to market.

The estimated quantity of grain moved from country elevators and subterminals to market is presented in Table 4-4. Among the five subterminals which ship the largest amounts of grain, four are located in the north with large marketing regions. The grain assemble patterns in this area may be more readily affected by the introduction of multiple-car rates.

25-Car Rail System

Minimum total cost occurs with ten subterminals in existence. Higher facility investment costs, coupled with relatively small decreases in multiple-car rail rates, for the 25-car system result in a cost increase for one fourth of one percent compared to the 10-car system.

Figure 4-4 presents the optimal grain flow from country elevators to subterminals. Subterminals in the north expand their marketing regions with the subterminal previously placed at Chinook becoming part of the region for Havre. The subterminal at Fort Benton became

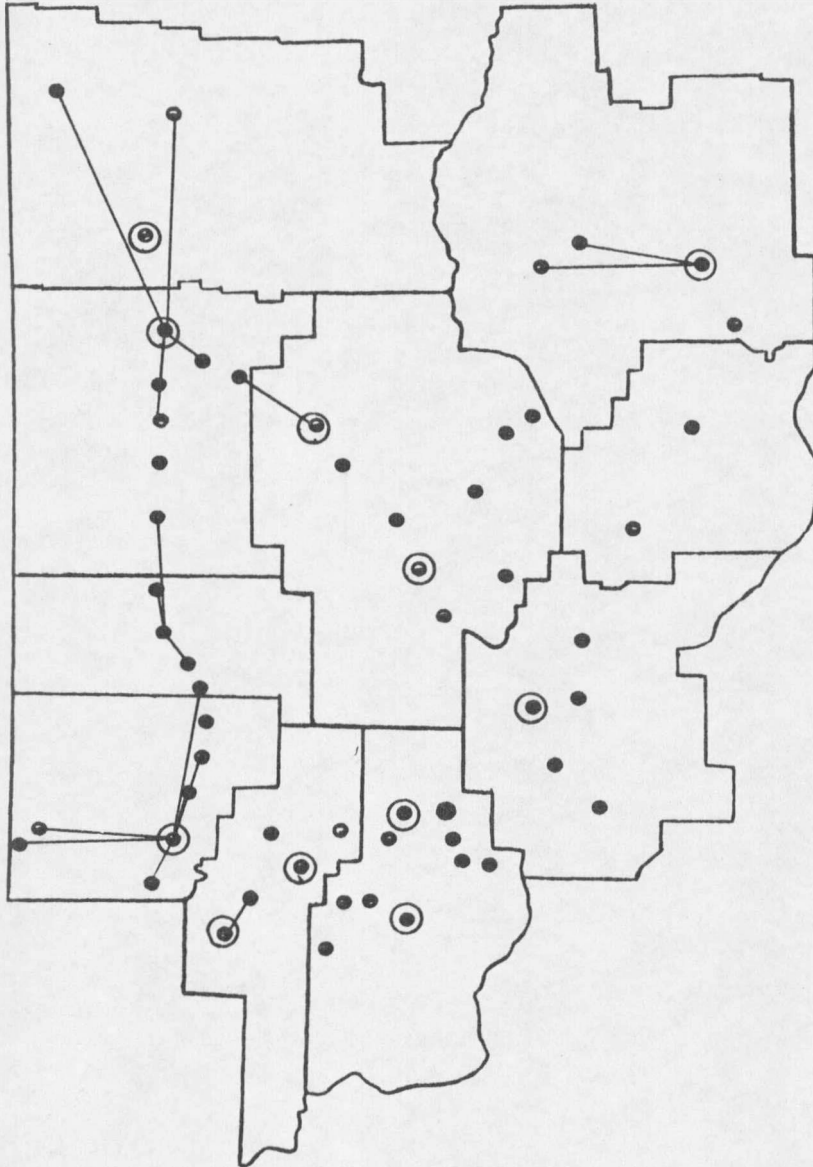


Figure 4-3. Estimated Grain Flow from Country Elevators to Subterminals for the 10-car Rail System, Golden Triangle Area.

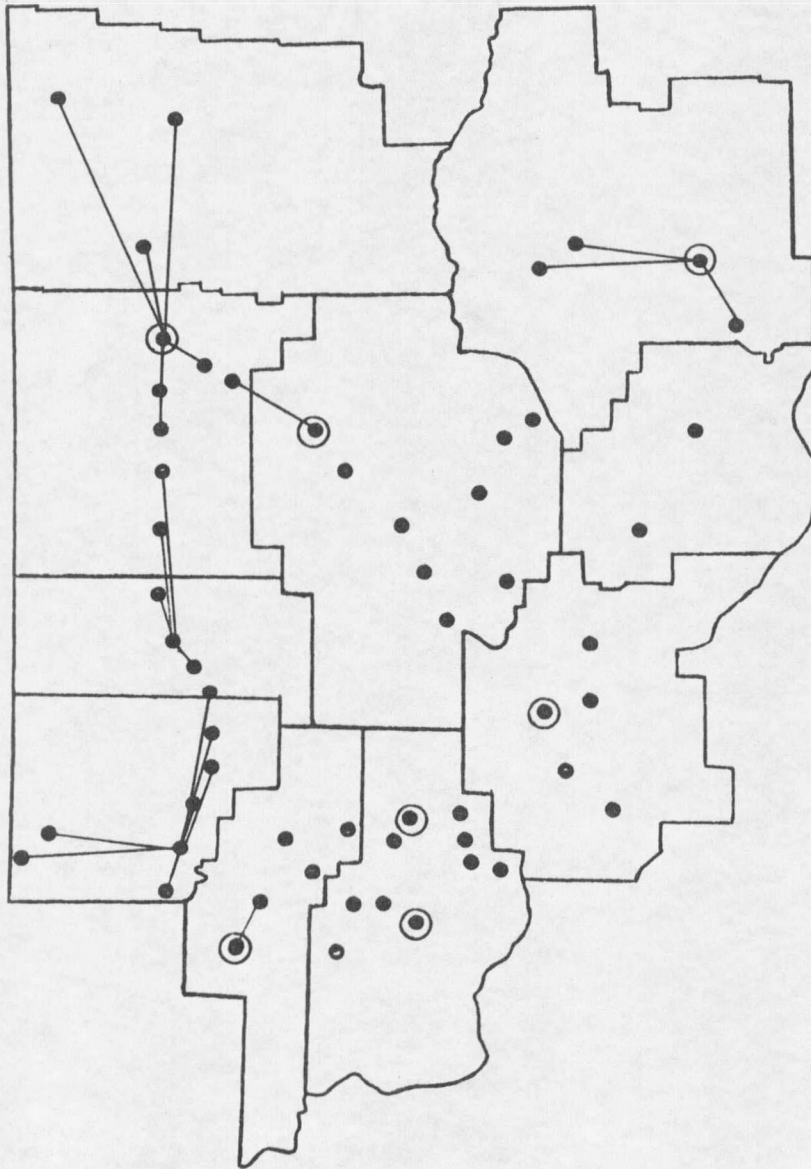


Figure 4-4. Estimated Grain Flow from Country Elevators to Subterminals for the 25-car Rail System, Golden Triangle Area.

Table 4-4

Estimated Grain Shipment from Country Elevators and
Subterminals to Market for the 10-car Rail System

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Grain Shipped
	(1,000 bu)	
Havre	8,279.7	15
Shelby	5,859.5	10
Great Falls	5,636.8	10
Chinook*	3,318.8	6
Chester	7,526.7	14
Big Sandy	6,019.5	11
Fort Benton	2,970.0	5
Lewistown	2,360.4	4
Choteau	580.9	1
Dutton	2,555.6	4
Conrad	4,763.8	8
Valier	2,485.4	4
TOTAL	53,357.10	
Single-Car Shipment to:		
West Coast	8,875.9	
Truck-Barge Shipment to:		
West Coast	9,001.8	

*The remaining subterminals are listed in the order they were selected.

too costly and this shipping origin and those in the southwest ship grain directly to market.

The estimated grain movement from shipping origins to market is shown in Table 4-5. Among the five subterminals handling the largest grain volume, three out of four in the north are shipping more grain compared with the 10-car system. The subterminal at Lewistown handles an increased percentage of grain.

50-Car Rail System

The optimal grain flow for the 50-car system is shown in Figure 4-5. In the central, southern, and western regions of the Golden Triangle Area, there are four subterminals receiving grain from country elevators which did not in the previous cases. In contrast to the 25-car system, the subterminal at Dutton was relocated to Fort Benton with enlarged marketing regions for Great Falls and Fort Benton.

Table 4-6 presents the estimated quantity of grain shipped to market for each elevator type. The relatively large percentage of grain previously handled by subterminals in the north is reduced and more is shipped from subterminals in Fort Benton and Great Falls. It is important to notice the 24 percent increase in the total quantity of grain handled by subterminals over that for the other two systems.

Table 4-5

Estimated Grain Shipment from Country Elevators and
Subterminals to Market for the 25-car Rail System

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Total Grain Shipped From Subterminals
	(1,000 bu)	
Havre	11,598.5	21
Shelby	6,385.6	12
Great Falls	5,636.8	10
Conrad*	4,763.8	8
Valier	2,485.4	4
Big Sandy	6,019.5	11
Chester	9,534.0	17
Dutton	2,555.6	4
Choteau	580.9	1
Lewistown	3,519.9	6
TOTAL	53,080.0	
Single-Car Shipment to:		
West Coast Seattle	7,614.1	
Truck-Barge Shipment to:		
West Coast Portland	10,540.7	

*The remaining subterminals are listed in the order they were selected.

Table 4-6

Estimated Grain Shipment from Country Elevators and
Subterminals to Market for the 50-car Rail System

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Total Grain Shipped From Subterminals
	(1,000 bu)	
Havre	11,598.5	18
Shelby	7,421.2	11
Great Falls	9,509.3	14
Conrad*	6,835.0	10
Big Sandy	6,019.5	9
Valier	2,485.4	3
Fort Benton	8,070.6	12
Lewistown	3,519.9	5
Choteau	1,161.6	1
Chester	9,534.0	14
TOTAL	66,155.0	
Movement by Single-Car Shipment to: Seattle	1,789.7	
Movement by Truck-Barge Shipment to: Portland	3,290.1	

*The remaining subterminals are listed in the order they were
selected.

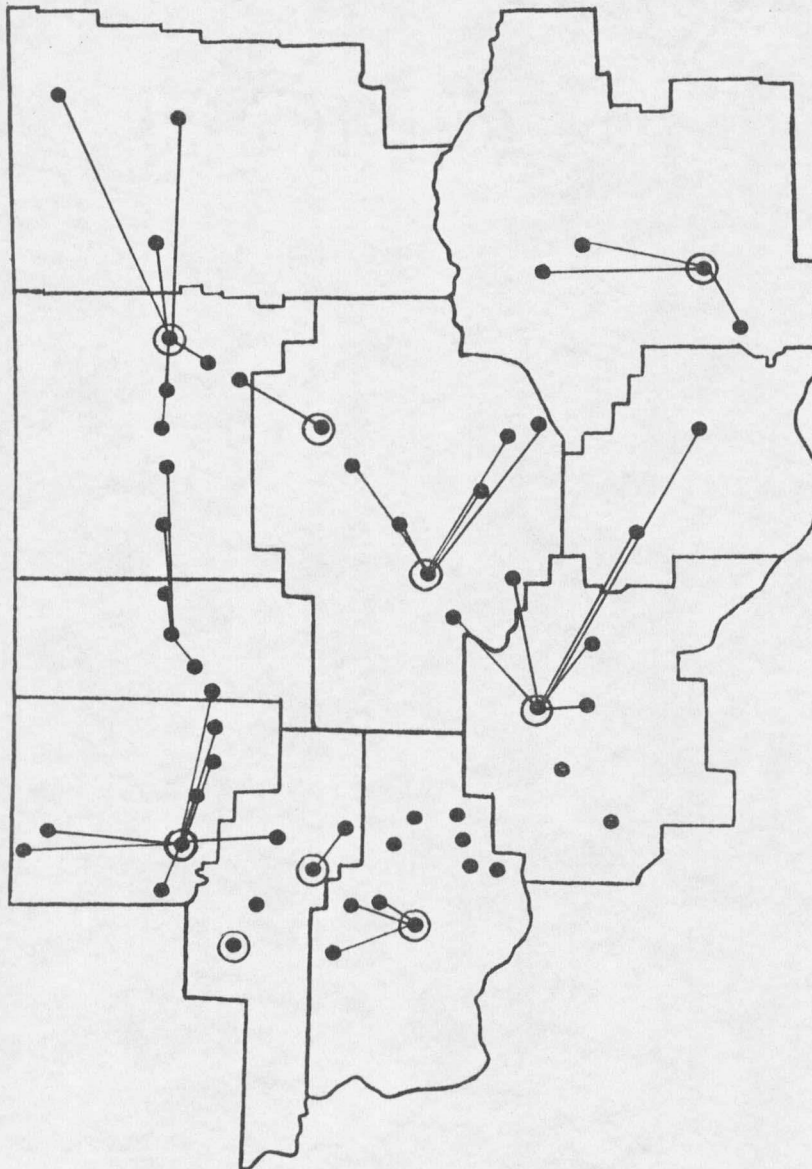


Figure 4-5. Estimated Grain Flow from Country Elevators to Subterminals for the 50-car Rail System, Golden Triangle Area.

Sensitivity of Results to Cost Changes

Since this study uses historical data to make future projections, it is important to examine the sensitivity of the optimal subterminal location and grain flow to cost changes. The estimated total marketing cost can be broken up into three categories: shipping costs, investment costs, and assembly costs. Variations in the cost data may change the optimal grain distribution system. The result of changing costs in each category is addressed to determine its effect on the optimal solution.

Interaction Between Investment Costs and Transportation Costs

Total investment cost has a direct relationship with the number of subterminals in a distribution system while total transportation and handling cost has an inverse relationship with subterminal number. The functional form of both relationships depends on the size of the multiple-car shipment associated with the system. Changes in the shipment size results in the rate of change increasing for the total investment cost and the total transportation and handling cost. Therefore, as the multiple-car shipment size increases, total cost will change at a faster rate, resulting in fewer subterminal in the optimal distribution system.

As the multiple-car shipment size increased from 10 to 25 there were two fewer subterminals placed in the system. With shipment

size increasing from 25 to 50, total investment cost and total transportation and handling cost did change at a faster rate, but no significant change occurred in the optimal subterminal number.

Figure 4-6 presents total investment cost and total transportation and handling cost as a function of subterminal number for the 25- and 50-car systems.

Assembly Costs

The estimated total marketing cost of the single-car system is composed entirely of the cost of shipping grain to final markets. With the introduction of multiple-car shipments, not all of the total cost of a multiple-car system is made up of shipping costs. Some grain is trucked from country elevators to subterminals with each multiple-car system. The total cost of each multiple-car system includes the cost of assembling grain for shipping and the cost of shipping the grain to market.

Since trucks are used to haul grain from country elevators to subterminals, the trucking rate is one component of assembly cost. The sensitivity of rail based distribution systems to varying assembly costs is examined through changes in the trucking rate. A ten percent increase and a ten percent decrease in the trucking rates for the 50-car system were the variations allowed. Table 4-7 shows the estimated total cost for these two variations.

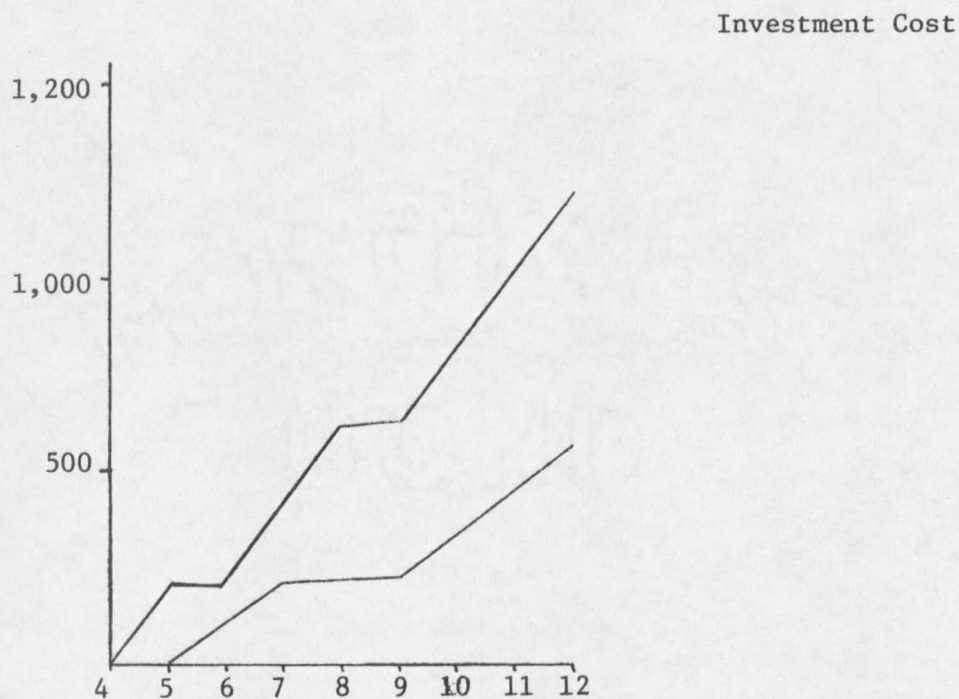
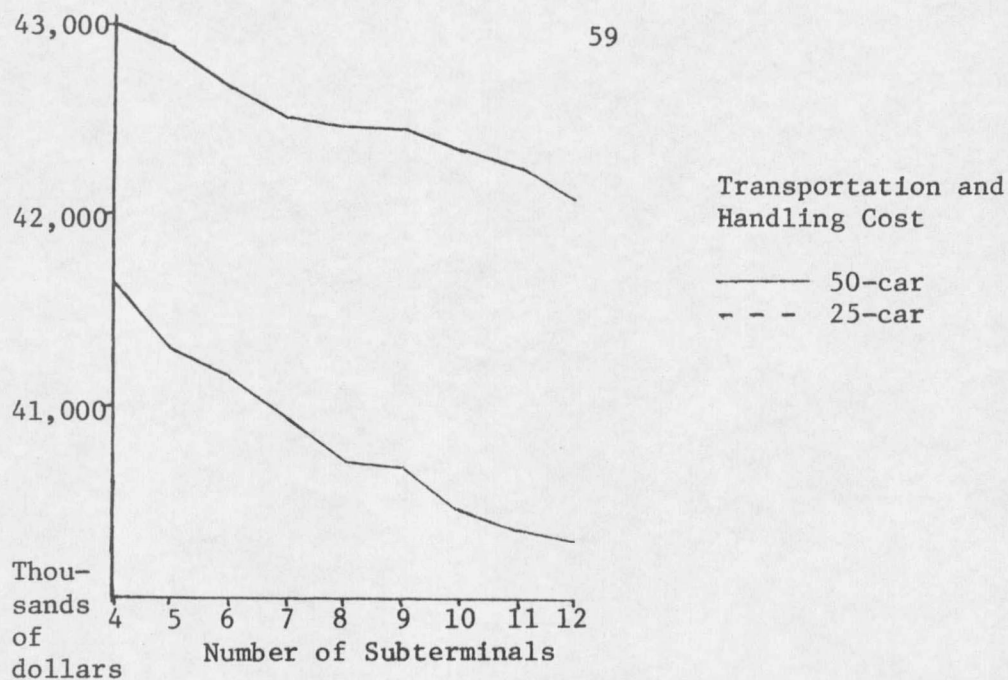


Figure 4-6. Estimated Total Investment Costs and Total Transportation and Handling Costs as a Function Subterminal Number for the 25- and 50-car Rail Systems.

Table 4-7

Estimated Total Marketing Costs for the 50-Car Rail System
With a Ten Percent Trucking Rate Increase and Decrease

Number of Subterminals	Total Marketing Cost With a 10% Trucking Rate Increase	Total Marketing Cost With a 10% Trucking Rate Decrease
4	\$41,806,416	\$41,426,080
5	41,639,552	41,300,096
6	41,496,400	41,189,008
7	41,461,120	41,176,064
8	41,425,888	*41,175,504
9	41,400,736	41,177,696
10	*41,388,032	41,212,624
11	41,470,272	41,291,952
12	41,614,896	41,453,264

*Minimum total cost indicating the optimal number of subterminals.

The estimated total cost for the 50-car system with a ten percent increase in trucking rates is two-tenths of one percent higher than that for the 50-car system and six percent lower than that for the single-car system. The 50-car system with a ten percent decrease in trucking rates has a total cost reduction of three-tenths of one percent over the 50-car system and six percent over the single-car system.

The optimal grain flow for the 50-car system with a ten percent increase in trucking rates is shown in Figure 4-7. Only one shipping origin changed marketing regions and trucks grain to Conrad rather than Choteau as in the 50-car case.

Table 4-8 presents the estimated grain movement to market. It is almost identical to the quantities of grain shipped through subterminals and directly to market for the 50-car system.

Figure 4-8 presents the optimal grain assembly patterns with a ten percent decrease in trucking rates. As shown, subterminals previously placed at Lewistown and Chester were deleted with this cost change, with the marketing region for Great Falls expanding to include four shipping origins that used to ship grain through Lewistown. The elevators which moved grain through Chester became part of the Shelby or Havre marketing area, depending on which had a cost advantage.

The estimated grain movement is shown in Table 4-9. The three

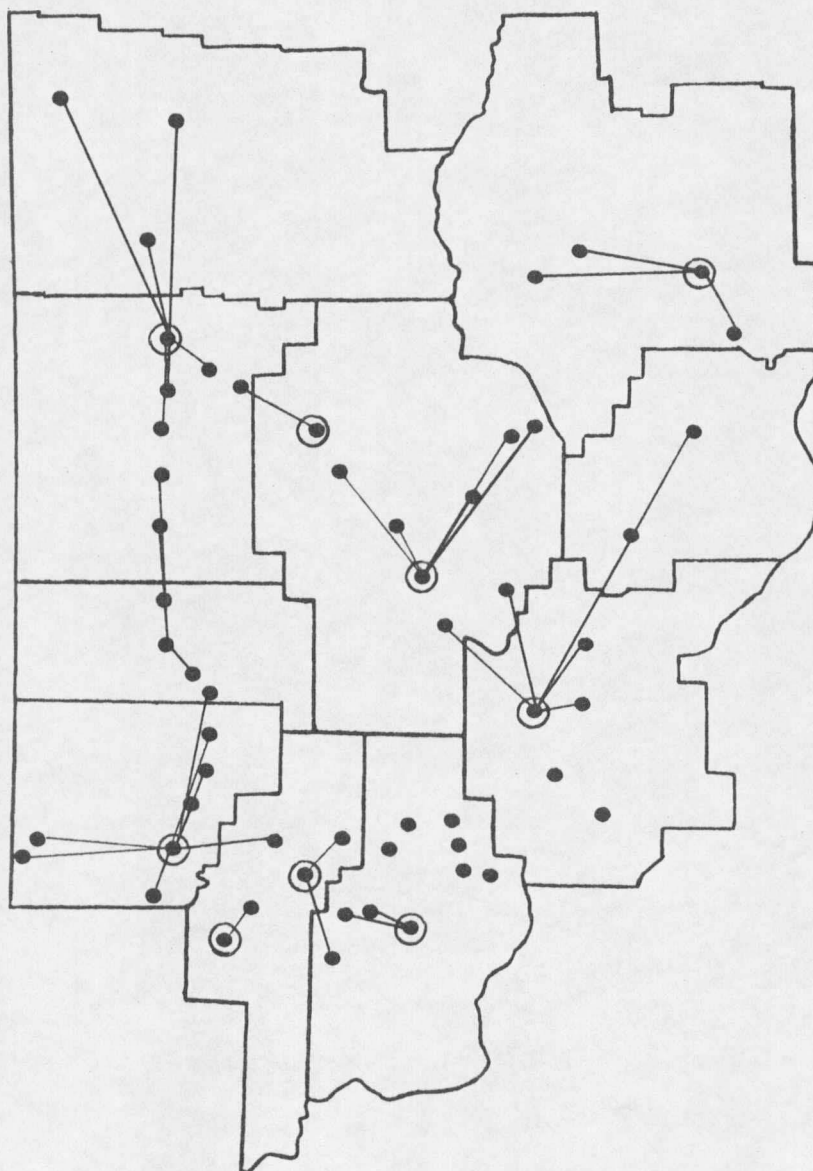


Figure 4-7. Estimated Grain Flow from Country Elevators to Subterminals for the 50-car Rail System with a Ten Percent Trucking Rate Increase, Golden Triangle Area.

Table 4-8

Estimated Grain Shipment from Country Elevators and
Subterminals to Market for the 50-Car Rail System
With a Ten Percent Trucking Rate Increase

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Total Grain Shipped From Subterminals
(1,000 bu)		
Hayre	11,598.5	17
Shelby	7,421.2	11
Great Falls	9,509.3	14
Conrad*	7,067.3	10
Big Sandy	6,019.5	9
Valier	2,485.4	3
Chester	9,534.0	14
Fort Benton	8,070.6	12
Lewistown	3,519.9	5
Choteau	929.3	1
TOTAL	66,155.0	
Movement by Single-Car Shipment to: Seattle	1,789.7	
Movement by Truck-Barge Shipment to: Portland	3,290.7	

*The remaining subterminals are listed in the order they were selected.

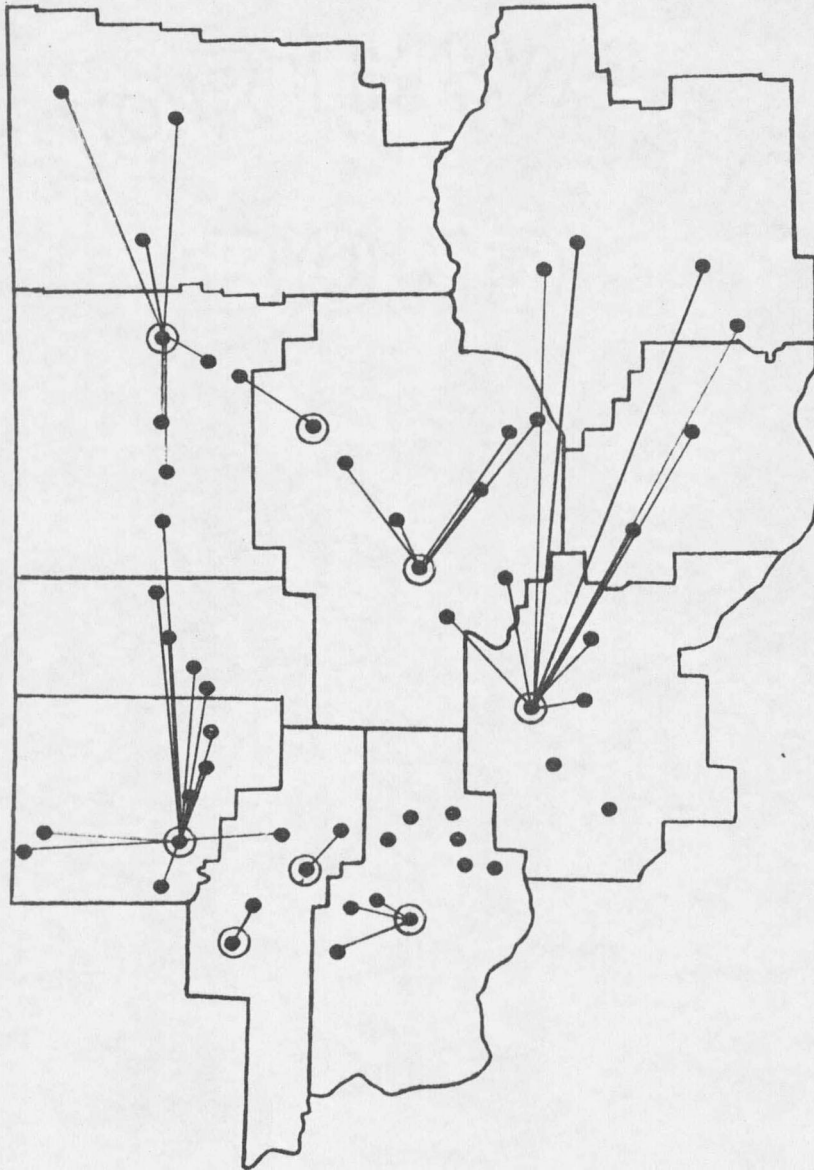


Figure 4-8. Estimated Grain Flow from Country Elevators to Subterminals for the 50-car Rail System with a Ten Percent Trucking Rate Decrease, Golden Triangle Area.

Table 4-9

Estimated Grain Shipment from Country Elevators and
Subterminals to Market for the 50-Car Rail System
With a Ten Percent Trucking Rate Decrease

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Total Grain Shipped From Subterminals
	(1,000 bu)	
Havre	13,605.8	20
Shelby	14,947.9	22
Great Falls	13,029.2	19
Conrad*	6,835.0	10
Valier	2,485.4	3
Big Sandy	6,091.5	9
Choteau	1,161.6	1
Fort Benton	8,070.6	12
TOTAL	66,227.0	
Movement by Single-Car Shipment to: Seattle	1,717.7	
Movement by Truck-Barge Shipment to: Portland	3,290.1	

*The remaining subterminals are listed in the order they were selected.

subterminals at Shelby, Havre, and Great Falls handle larger percentages of grain. However, the trucking rate decrease resulted in only a slight change in the total amount of grain handled by subterminals.

Increased assembly costs caused a slight variation in grain shipment patterns. However, decreased assembly costs did result in decreased investment with two fewer subterminals in use. This reduction in the total investment cost was greater than the increase in the total assembly cost.

Shipping Costs

Shipping costs will be affected by changes in rail and barge rates. The estimated 50-car rail rates represented, on the average, a twelve percent reduction from the 1976 single-car rates. These single-car rates were over two and one half times larger than the estimated single-car variable costs. Since the ratio of single-car rates to single-car variable cost was used in conjunction with the estimated 50-car variable cost in determining the estimated 50-car rate, the estimated 50-car rate reflected this substantial spread between the rail rate and the variable rail cost. Since the railroad in Montana is regulated to guard against excessive profits from high rates, the 50-car rate offered by the railroad may be lower than the estimated 50-car rate. This would enable subterminals to

ship grain to market at an even lower cost. Table 4-10 presents the estimated total marketing costs for the 50-car system with an eight percent reduction in the multiple-car rail rate.

The estimated total cost for the 50-car system with a reduction in the multiple-car rate was thirteen percent lower than the cost for the single-car system. Compared to the 50-car system with no rate reductions, there was a seven percent cost reduction.

The optimal grain flow is presented in Figure 4-9. The grain from all shipping origins moves through one of ten subterminals for shipment to market. Subterminals at Great Falls, Chouteau, and Conrad have expanded marketing areas compared to the 50-car case.

Table 4-11 shows the estimated grain movement to market. As the percentage of grain handled at Great Falls and Conrad increases, these two subterminals become more significant. The increase in the amount of grain handled at Choteau does not put this subterminal in the prominent higher volume category.

The reduction in shipping cost did result in the assembly of grain at subterminals having a cost advantage. The decrease in the total shipping cost was greater than the increase in the total assembly cost.

Table 4-10

Estimated Total Marketing Costs for the 50-Car Rail System
With An Eight Percent Multiple-Car Rail Rate Decrease

Number of Subterminals	Total Marketing Cost With an 8% Rail Rate Decrease
4	\$38,866,000
5	38,702,944
6	38,567,744
7	38,504,640
8	38,449,952
9	38,403,456
10	*38,386,880
11	38,450,032
12	38,592,464

*Minimum total cost indicating the optimal number of subterminals.

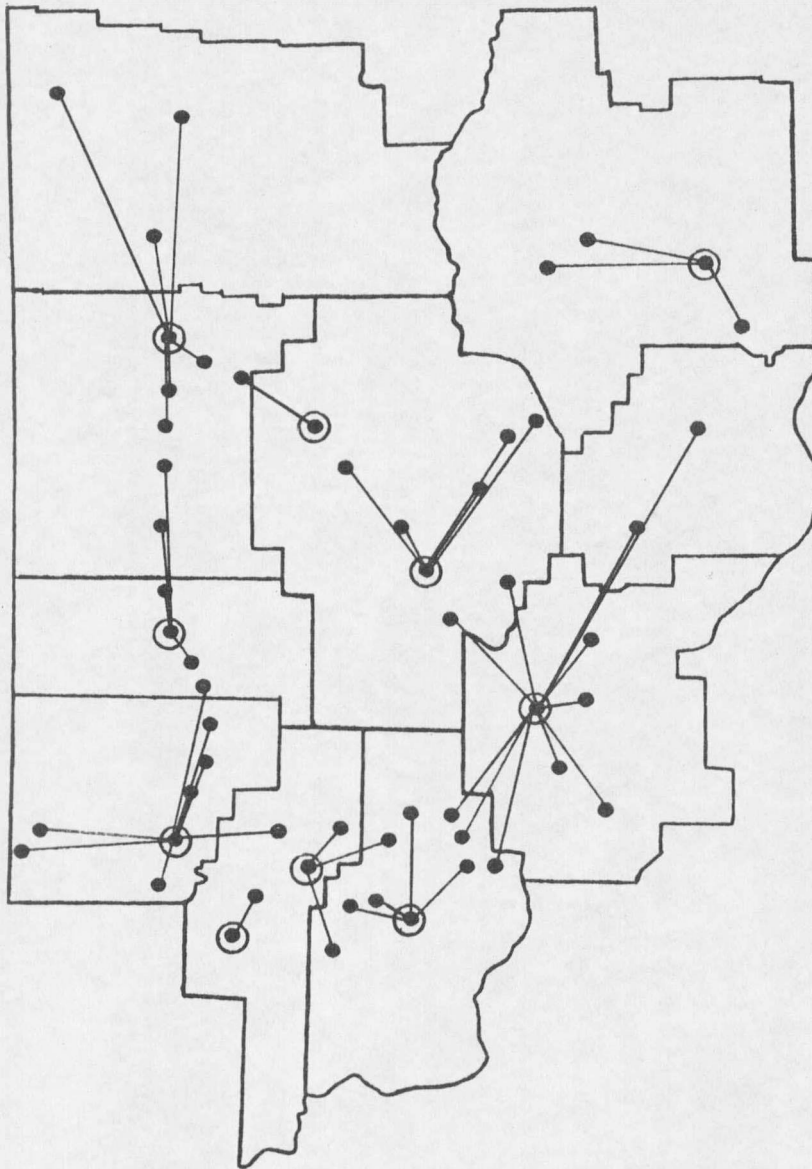


Figure 4-9. Estimated Grain Flow from Country Elevators to Subterminals for the 50-car Rail System with an Eight Percent 50-car Rail Rate Decrease, Golden Triangle Area.

Table 4-11

Estimated Grain Shipment from Country Elevators and Subterminals to
Market for the 50-Car Rail System With an Eight Percent
Multiple-Car Rail Rate Decrease

Movement by Multiple-Car Shipment From:	Quantity of Grain Shipped	Percentage of Total Grain Shipped From Subterminals
	(1,000 bu)	
Havre	11,598.5	16
Shelby	7,421.2	10
Great Falls	11,685.0	16
Conrad*	7,357.7	10
Big Sandy	6,019.5	8
Valier	2,485.4	3
Fort Benton	8,070.6	11
Lewistown	3,519.9	4
Choteau	3,543.0	4
Chester	9,534.0	13
TOTAL	71,234.8	

*The remaining subterminals are listed in the order they were
selected.

Chapter 5

SUMMARY AND CONCLUSIONS

In 1974-75, 92 percent of the wheat and 74 percent of the barley grown in Montana was shipped to markets in Seattle and Portland. Since these markets are over 700 miles away, transporting Montana grain to market is costly. Keeping this marketing cost down will help Montana keep farm incomes up.

Railroads in several states have issued multiple-car tariffs in an attempt to provide more transportation capacity. These multiple-car rates have a cost advantage over single-car rates; making rail transportation relatively more competitively priced with other modes of transportation. Establishment of multiple-car rates is a controversial issue in Montana.

Substantial investments in country elevators are necessary to make them capable of loading multiple-car shipments. This investment cost introduces much uncertainty regarding the costs for the alternative grain distribution systems. There is a need to know where investments should be made to insure the costs for each system are minimal.

The objective of this study was to determine the grain distribution system exhibiting minimum total cost in a ten-county region around the triangular area formed by Great Falls, Shelby, and Havre,

Montana. Total cost included transportation costs, variable handling costs, and facility investment costs for transporting the projected 1990 volume of 71 million bushels of grain sold from all country elevators in the Golden Triangle Area to one or more of three final markets. The means of grain transportation considered were single-car rail shipments, multiple-car rail shipments of 10-, 25-, and 50-cars, truck, and truck-barge.

The multi-stage transshipment model was developed to determine the grain distribution system with the lowest cost. The model required data including the amount of grain sold out of the area in 1990, transportation rates, investment costs, and handling costs.

The optimal grain flow for the 1976 single-car system included the shipment of 70 percent of the grain moved by single-car rail and 30 by truck-barge. Most shipping origins in the northern section of the Golden Triangle Area have a cost advantage shipping by rail while those in the southwestern region find truck-barge shipment a better alternative. If rail rates were adjusted to reflect the density difference between wheat and barley, more barley would move by truck-barge rather than rail.

Alternative Multiple-Car Systems

With the 50-car rail system, 93 percent of the grain was assembled at subterminals while, of the remaining grain, five percent moved

directly to market by truck-barge and two percent by single-car shipment. For the 25-car and the 10-car systems, 74 percent was assembled at subterminals with 14 percent using the truck-barge combination and 12 percent using single-car shipments to move to market.

The estimated total cost for each multiple-car system was less than that for the single-car system. The cost reduction varied with a three, two, and five percent reduction for the 10-, 25-, and 50-car systems, respectively. The substantial investments necessary to construct 25-car loading facilities result in higher costs for that system even though subterminals handled the same total percentage of grain as in the 10-car case. This higher cost for moving nearly identical quantities of grain may make the 25-car system the least desirable of the three.

The optimal number of subterminals for the 25-car and 50-car systems was ten. Due to low investment costs, twelve subterminals were placed in the 10-car system. The locations of subterminals and the quantity of grain handled by each one varied depending on the system in question.

The 50-car system did have the lowest estimated cost, but the grain movement patterns which actually develop in this area depend on many things. First, in 1976 no multiple-car rates were offered by the railroad. The multiple-car rates which may be offered in the

future will affect the cost advantage of assembling grain at subterminals for multiple-car shipment to market. As multiple-car rates relative to single-car rates become lower, grain assembly will have an increasing cost advantage.

There are certain cost considerations which could be made before each individual subterminal is constructed. Investment in a subterminal is feasible only if the yearly cost of the construction or upgrading is covered by savings in shipping and handling costs. All grain moved from farms to subterminals has reduced handling and shipping costs compared to grain moved from farms to country elevators. However, grain trucked from country elevators through subterminals has extra handline charges and increased assembly costs to be added to investments before the comparison to the shipping costs savings is made. It may require a large volume of grain to be moved by a subterminal before the savings in this case are equal to the costs. Before any construction or upgrading takes place, it becomes advantageous for elevator operators to analyze their grain receipts and determine the volume expected to be received from farmers and country elevators. A high volume coupled with a large movement of grain from farms may give a subterminal a relative cost advantage. After each one is examined individually, some subterminals placed in the rail based systems may be found infeasible and would never be constructed.

Effect of Rate Structure Variations on Distribution Systems

The subterminal locations and the sizes of the marketing regions for each subterminal were sensitive to shipping, assembly, and investment costs. An eight percent reduction in the 50-car rate resulted in all the grain in the area being shipped to market from subterminals and a thirteen percent reduction in total marketing cost compared to the single-car system. With trucking rates decreasing or increasing by ten percent, the percentage of grain assembled at subterminals and the percentage moved directly to market remained the same. However with the trucking rate decrease, there were two fewer subterminals placed in the system and a cost reduction of six percent over the single-car system. Total marketing cost was more sensitive to variations in shipping costs than in assembly costs, indicating shipping cost is a more significant component of total cost.

This study was completed for ten counties in the Golden Triangle Area in Montana. Under the assumptions made in the study, the results can be applied directly only to that area. However, insight may be provided into the efficiency of other grain distribution systems which should not be overlooked.

Institutional Problems in Implementing Alternatives

Several problems could possibly arise with the implementation of any of the alternative grain distribution systems. Historically, the

interaction between the railroad and representatives for the grain industry has been marked with conflict. Any lack of cooperation between the two would pose a problem if a rail-based grain distribution system were implemented.

A second possible problem is the questionable condition of some track in the Golden Triangle Area. The railroad feels the maintenance costs for keeping a section of track in usable condition is too high to warrant undertaking its further maintenance. The section of track runs from Agawam to Lewistown with a spur line to Winifred. Country elevators on this particular line may be unable to ship any grain by rail unless this track is maintained.

Since each country elevator and subterminal will be associated with one of the competing grain marketing companies in the region, there may be unwillingness on the part of both parties to work together. Subterminal operators may attempt to compete with country elevators for business. Country elevator operators may feel systems with subterminals reduce their marketing options. Since only a single-car system required no subterminals, this lack of cooperation will present a possible problem. Country elevator operators and subterminal operators must work together to obtain the reduced total cost of an alternative system.

Suggestions for Further Research

The scope of this research could be enlarged to include one or more of the possible extensions suggested for this study. The first possible extension is the inclusion of the farm sector; farms becoming the point of origin for grain movement. Expansion of the study to a state level would be a second possible extension. These two extensions would yield a more comprehensive analysis of the impact of each grain distribution system. A third area for further research concerns changing the time period for grain movement from a yearly flow to a monthly flow. This further research would result in estimates for storage requirements each month and for the optimal timing of grain flow to market for the year.

A fourth area for additional research is into the potential of a rail-barge system. There are rail lines to water access points in the barge system which could be used in an attempt to reduce costs.

The final markets in this study were assumed to be capable of receiving all Montana grain shipped to them. An analysis of the impact of alternative grain distribution systems on final markets would be a fifth possible extension of this research.

A sixth area for additional research would be to examine and incorporate any economies of scale for grain handling facilities. The grain handling costs used in this study represented constant marginal costs.

A seventh possible area for extension would include an analysis of the impact of alternative systems on highway and rail line maintenance. The effect of increased use of maintenance costs is important information.

The analysis of distribution systems for any agricultural product would be facilitated if the relevant data was continually maintained. There is a need to develop and establish procedures for this data collection to aid any further research done on distribution systems for agricultural products.

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APPENDICES

Appendix A

Estimated Wheat and Barley Sale in 1,000 Bushels for 1900
By Shipping Origin, Golden Triangle Area

No.	Location	Surplus Wheat in 1990 (in 1000 bu)	Surplus Barley in 1990 (in 1000 bu)
1	Hogeland	433.1	166.3
2	Harlem	673.2	258.5
3	Chinook	2,398.3	920.5
4	Havre	3,687.3	442.1
5	Fresno	819.4	98.3
6	Kremlin	1,416.9	169.9
7	Gildford	1,792.4	214.9
8	Rudyard	2,321.6	278.4
9	Joplin	1,447.7	358.6
10	Chester	1,499.2	369.1
11	Tiber	1,009.5	242.6
12	Lothair	339.4	84.4
13	Galata	327.2	198.9
14	Devon	263.6	129.6
15	Dunkirk	25.7	15.6
16	Sweetgrass	51.5	31.3
17	Sunburst	415.5	252.5
18	Shelby	2,566.3	1,560.0
19	Ethridge	77.2	46.9
20	Laredo	102.4	12.3
21	Box Elder	1,126.7	135.1
22	Big Sandy	3,480.6	1,277.1
23	Virgelle	258.7	95.3
24	Loma	1,000.0	244.7

Appendix A Continued

No.	Location	Surplus Wheat in 1990 (in 1000 bu)	Surplus Barley in 1990 (in 1000 bu)
25	Fort Benton	2,480.6	489.4
26	Carter	2,052.0	489.4
27	Winifred	291.8	67.5
28	Suffolk	132.6	30.7
29	Lewistown	1,700.1	137.7
30	Moore	941.7	217.8
31	Square Butte	480.5	176.3
32	Geraldine	2,389.7	219.2
33	Montague	181.8	54.4
34	Highwood	571.4	134.0
35	Windham	271.0	101.3
36	Geyser	93.9	35.2
37	Belt	53.6	10.1
38	Lavin Spur	53.6	7.0
39	Great Falls	4,929.9	706.9
40	Ulm	160.8	28.8
41	Cascade	160.8	25.7
42	Fairfield	630.8	413.7
43	Power	445.3	251.7
44	Cordova	37.1	21.0
45	Cleiv	37.1	21.0
46	Agawam	111.3	62.9
47	Farmington	111.3	62.9
48	Choteau	371.1	209.8
49	Pendroy	148.4	83.9
50	Dutton	1,632.7	922.9
51	Collins	185.5	104.9
52	Brady	997.1	1,074.1
53	Conrad	2,293.4	2,470.4
54	Ledger	498.6	537.0
55	Williams	99.7	107.4
56	Valier	<u>1,096.8</u>	<u>1,181.5</u>
TOTAL		53,175.4	18,059.4

Appendix B-1

The 1976 Single-Car Rail Rates per cwt by Destination, Type of Grain, and Elevator Location, Golden Triangle Area

Elevator Locations and Reference Numbers									
No.	Location	To West Coast	To Minneapolis Wheat	Barley	No.	Location	To West Coast	To Minneapolis Wheat	Barley
1	Hogeland	135	164	153	29	Lewistown	109	164	144
2	Harlem	118	164	144	30	Moore	109	164	144
3	Chinook	113.5	164	144	31	Square Butte	102.5	164	144
4	Havre	109	164	144	32	Geraldine	102.5	164	144
5	Fresno	109	164	147.5	33	Montague	102.5	164	144
6	Kremlin	109	164	147.5	34	Highwood	100	164	144
7	Gildford	109	164	147.5	35	Windham	109	164	144
8	Rudyard	109	164	147.5	36	Geyser	105	164	144
9	Joplin	106	164	147.5	37	Belt	102.5	164	144
10	Chester	106	164	147.5	38	Lavin Spur	100.5	164	144
11	Tiber	105	164	147.5	39	Great Falls	98.5	164	144
12	Lothair	105	164	147.5	40	Ulm	98.5	164	145.5
13	Galata	102.5	164	147.5	41	Cascade	98.5	164	151
14	Devon	102.5	164.0	147.5	42	Fairfield	100.5	164	144
15	Dunkirk	102.5	164.0	147.5	43	Power	100.5	164	144
16	Sweetgrass	112.5	164	155.5	44	Cordova	102.5	164	144
17	Sunburst	105	164	150.5	45	Cleiv	102.5	164	144
18	Shelby	102.5	164	147.5	46	Agawam	102.5	164	144
19	Ethridge	102.5	164	147.5	47	Farmington	102.5	164	144
20	Laredo	109	164	144	48	Choteau	102.5	164	144
21	Box Elder	109	164	144	49	Pendroy	102.5	164	147.5
22	Big Sandy	106	164	144	50	Dutton	102.5	164	144
23	Virgelle	106	164	144	51	Collins	102.5	164	147.5
24	Loma	102.5	164	144	52	Brady	102.5	164	147.5
25	Fort Benton	102.5	164	144	53	Conrad	102.5	164	147.5
26	Carter	100.5	164	144	54	Ledger	102.5	164	147.5
27	Winifred	118.5	164	164	55	Williams	102.5	164	147.5
28	Suffolk	113.5	164	164	56	Valier	102.5	164	147.5

Appendix B-2

The Estimated 1976 10-Car Rail Rate per cwt by Destination, Type of Grain, and Elevator Location, Golden Triangle Area

Potential Subterminal Locations and Reference Numbers						
Location	To Portland		To Seattle		To Minneapolis	
	Wheat	Barley	Wheat	Barley	Wheat	Barley
Chinook	109.6	109.6	109.0	109.4	153.6	134.6
Havre	102.5	102.4	101.4	102.0	153.7	135.4
Chester	100.5	101.1	99.7	100.0	155.1	139.9
Shelby	95.0	95.0	94.4	94.4	155.7	140.3
Big Sandy	102.0	105.9	101.5	101.8	154.7	135.8
Fort Benton	97.7	98.4	97.0	97.5	154.9	136.8
Lewistown	104.1	104.5	102.2	102.6	155.9	137.6
Great Falls	92.0	92.1	91.5	91.3	155.7	135.3
Choteau	95.7	96.3	95.3	96.6	156.6	138.2
Dutton	95.7	96.0	95.1	95.1	157.4	138.9
Conrad	97.6	97.6	96.8	96.9	156.2	140.8
Valier	95.9	96.1	95.0	95.0	156.4	141.1

Appendix B-3

The Estimated 1976 25-Car Rail Rate per cwt by Destination, Type of Grain, and Elevator Location, Golden Triangle Area

Potential Subterminal Locations and Reference Numbers						
Location	To Portland		To Seattle		To Minneapolis	
	Wheat	Barley	Wheat	Barley	Wheat	Barley

Chinook	108.3	108.4	107.7	108.1	152.1	133.1
Havre	101.3	101.3	100.2	100.8	151.9	133.6
Chester	99.5	99.9	98.6	98.7	153.3	138.1
Shelby	94.0	93.9	93.3	93.4	153.7	138.6
Big Sandy	100.8	104.8	100.2	100.7	152.9	134.0
Fort Benton	96.5	97.3	95.8	96.3	153.2	135.1
Lewistown	102.9	103.1	101.0	101.5	154.6	136.0
Great Falls	91.0	91.0	90.3	90.2	154.0	133.6
Choteau	94.6	95.2	94.4	94.5	154.9	136.4
Dutton	94.8	94.9	94.1	93.9	155.6	137.2
Conrad	96.6	96.9	95.7	95.8	154.3	139.1
Valier	94.7	95.9	94.0	93.9	154.5	139.5

Appendix B-4

The Estimated 1976 50-Car Rail Rate per cwt by Destination, Type of Grain, and Elevator Location, Golden Triangle Area

Potential Subterminal Locations and Reference Numbers						
Location	To Portland		To Seattle		To Minneapolis	
	Wheat	Barley	Wheat	Barley	Wheat	Barley
Chinook	102.6	102.5	101.9	102.1	144.0	126.1
Havre	96.0	95.8	94.9	95.1	144.0	126.4
Chester	94.1	94.5	93.1	93.1	145.1	130.8
Shelby	88.8	88.7	87.9	88.0	146.0	131.3
Big Sandy	95.6	99.1	94.9	95.2	145.1	127.0
Fort Benton	91.5	92.1	90.7	90.9	145.4	128.1
Lewistown	97.7	98.0	95.7	95.8	146.3	128.8
Great Falls	86.1	86.1	85.3	85.1	146.2	126.7
Choteau	89.8	90.2	89.2	89.4	147.1	129.4
Dutton	89.6	89.8	89.0	88.6	148.0	130.2
Conrad	91.2	91.6	90.3	90.5	146.5	131.9
Valier	89.6	89.8	88.8	88.7	146.6	132.4

Rail based grain distribution systems ...

DATE	ISSUED TO
FEB 25 1968	K. W. P. RECHT 6165 Geneva
	Robin Conner 6-6751 3493 S. ...
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