OPTIMAL LONG RUN TRANSPORTATION ADJUSTMENTS FOR COUNTRY GRAIN ELEVATORS IN OKLAHOMA

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PREFACE

This study is concerned with developing a systematic approach to guide the country grain elevator owner or manager in the optimal selection of available transportation alternatives. This systematic approach utilizes a mixed integer programming model to determine the optimal transportation alternatives. The mixed integer programming model is demonstrated by using data from a country grain elevator located in northwestern Oklahoma

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CHAPTER I

INTRODUCTION

Transportation plays a vital role in the financial success of country grain elevators. Railroads have been especially important in the movement of grain from Oklahoma elevators to domestic and export markets. Recent railroad line abandonments and bankruptcy of the Chicago, Rock Island and Pacific Railroad have left availability of railroad services to Oklahoma elevators in a cloud of uncertainty. Country grain elevator owners and managers are likely to be developing transportation contingency plans for use in the event of rail service being discontinued. The results of research reported in this study provide a systematic means by which elevator owners and managers can evaluate alternative adjustments in their transportation patterns in the event of local rail line closure.

Rail Line Abandonment in Oklahoma

Substantial rail abandonment activity has taken place in Oklahoma since 1970 and more is expected. Rail line closure results from two types of circumstances. First, traffic deterioration on a particular segment of a solvent railroad may present expected financial losses with continued service on the line segment. Secondly, railroad company insolvency may result in a package of line closures as assets of the company are liquidated. The rate at which line abandonment cases are initiated will likely accelerate with new federal branch line policy outlined in the Railroad Revitalization and Regulatory Reform Act of 1976.

Rail Abandonment Since 1970

A total of 15 rail abandonment cases affecting Oklahoma track mileage have been considered since April, 1970.[1] Eleven of those cases, involving 521 miles of track, have been granted. This is approximately 10 percent of the Class I railroad track in Oklahoma. Abandonment of another 217 miles of track is pending a decision from the Interstate Commerce Commission, as of June 15, 1976. Table I shows the name of the railroad involved, the length of track, location and disposition of each rail abandonment case in Oklahoma since 1970.

Traffic Deterioration as a Cause for Rail Abandonment

Rail service to a line segment may be discontinued when traffic deterioration leads to expected future financial loss by the operating railroad. Traffic deterioration may be caused by weight limits enforced on that line segment. Such weight limits may prevent the use of the newer 100 ton hopper cars. Over 750 miles (or 14.4%) of Oklahoma rail is classified as light density line.[2] Light density line is defined as any line segment unable to support a loaded rail car weighing 263,000 pounds. Some of this light density line is located in the heart of Oklahoma's grain producing region. A diagram indicating the location of light density line in Oklahoma is shown in Figure 1.

TABLE I

OKLAHOMA RAIL ABANDONMENT CASES SINCE 1970
TOTAL OF 15 CASES AS OF JUNE 15, 1976

Railroad	Length (miles)	Location	Date Granted
Texas-Pacific	12.98	Barnsdall-Pawhuska	Pending
Santa Fe	30.00	Ardmore-Ringling	Pending
Santa Fe	38.50	Cushing-Shawnee	Pending
Missouri-Kansas-Texas	136.00	Bartlesville-Oklahoma City	Pending
Santa Fe	12.01	Burbank-Fairfax	10-8-75
Hollis and Eastern	21.00	Duke-Hollis	5-7-75
Missouri-Kansas-Texas	225.34	Altus-Forgan	11-18-71
BME	105.65	Beaver-Keyes	11-18-71
Santa Fe	30.15	Abandonment in Oklahoma and Pottawatomie Counties	
Texas Pacific	4.03	In Tulsa County, Oklahoma	1-11-71
Santa Fe	17.17	Ada-Tupelo	7-6-72
St. Louis-San Francisco	35.00	In Okmulgee and Muskogee Counties	10-13-71
Santa Fe	39.78	Paul's Valley-Ada	8-31-71
Santa Fe	23.80	Newkirk-Burbank	8-31-71
Santa Fe	7.70	Esau Junction-Pawnee	2-16-73
Total Cases Pending: 4	Miles Requested: 217.48	Miles Granted: 0	
Total Cases Granted: 12	Miles Requested: 521.63	Miles Granted: 521.63	

Railroad	Mileage	% of Okla. Mileage
Santa Fe	15.7	1.2%
Rock Island	236.3	23.4%
KC Southern	49.3	38.6%
Katy	69.0	9.0%
Mo-Pac	89.7	18.0%
Frisco	292.8	21.4%
Total	752.8	14.4%

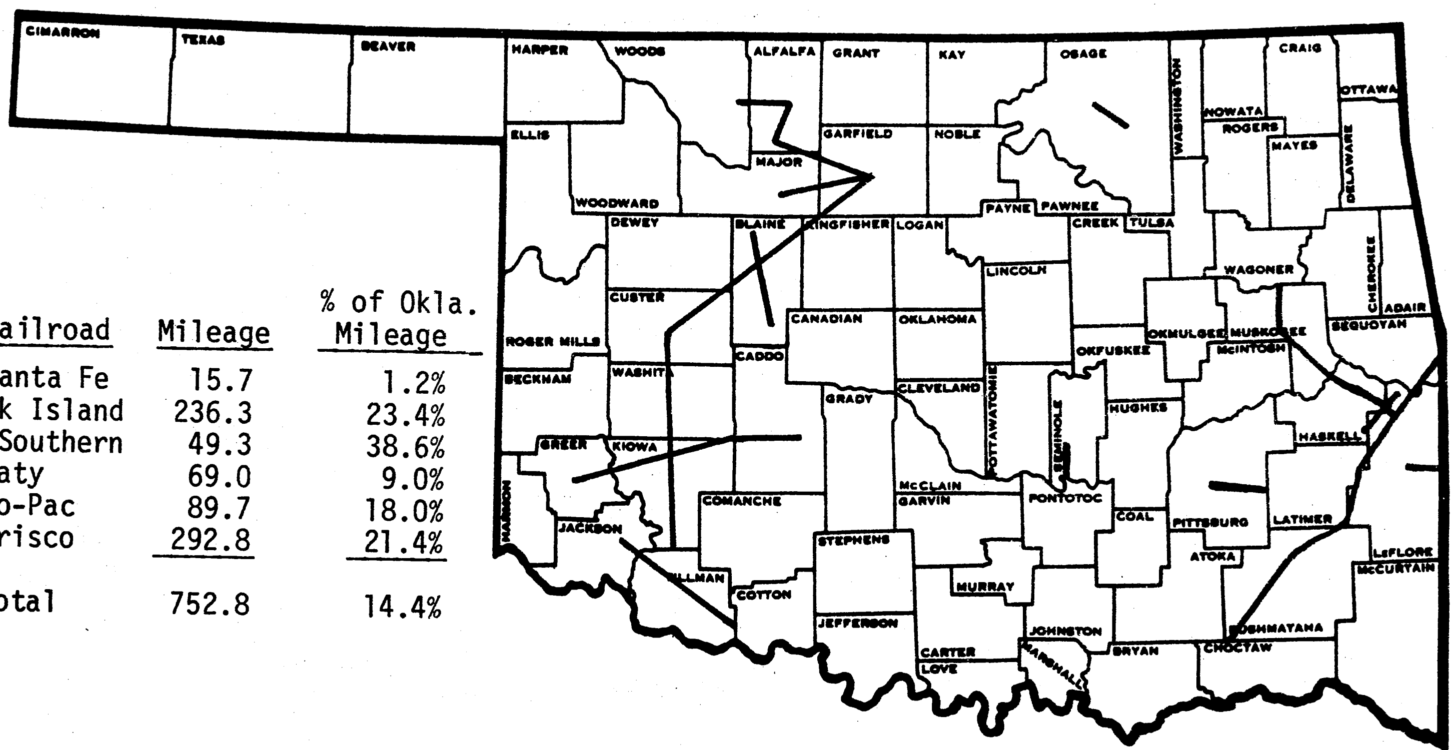

Figure 1. Light Density Rail in Oklahoma

The existence of light density line may lead to abandonment for three reasons: (1) high railroad operating costs, (2) reduced rail service leading to a lower volume of traffic, and (3) high rehabilitation costs to maintain competitive service. The cost of operating on light density track becomes higher as the railroad is forced to use older equipment to service customers on the line, rather than taking advantage of newer, more efficient equipment. The presence of light density line also forces the railroad to use older equipment, which is more susceptible to grain loss. Finally, the cost of rehabilitating a segment of light density track to a level that would remove weight limitations is often greater than the revenues generated by the rehabilitation. The result is that operating costs continue to increase while service continues to decline. The eventual end is abandonment of the rail segment.

Railroad Company Insolvency as a Cause for Rail Abandonment

A second circumstance which may lead to rail line abandonment is the financial failure of a railroad company. Two railroads serving Oklahoma have filed for or are near bankruptcy. The Chicago, Rock Island and Pacific Railroad filed for bankruptcy in 1975. The Missouri-Kansas-Texas Railroad (Katy) is on the verge of financial collapse. The bankrupt Northeastern railroads were unable to reorganize on an income basis because ordinary company income had been negative for several years prior to bankruptcy. In addition, the Northeastern railroads had operating ratios of well over 80 percent when bankruptcy occurred. The operating ratio is a ratio of operating expenses to operating revenues. At the time of bankruptcy, the Northeastern railroads were spending well over 80 cents of every dollar of operating revenue to pay operating expenses. This may be compared with operating ratios of near 70% for some of the more financially sound railroads in the country.

The financial conditions of the bankrupt Northeastern railroads, along with the Rock Island and Katy railroads, are shown in Tables II and III. A comparison of the information given in Tables II and III shows that the Rock Island and Katy railroads have symptoms similar to the bankrupt Northeastern railroads.

Table II shows that current assets were less than current liabilities for several years preceding the bankruptcy of each of the seven Northeastern railroads. Total current assets represent cash on hand and income immediately receivable, which can be used to cover expenses as they come due. Total current liabilities are expenses currently due for such items as taxes accrued, outstanding wages payable and unpaid interest on matured long term debt. A cash flow problem is created when current liabilities exceed current debt over several years. As previously discussed, the operating ratios given in Table II become increasingly higher in years immediately preceding bankruptcy.

Net railway operating income and ordinary company income for each of the seven bankrupt Northeastern railroads is also gives in Table II. Net railway operating income is the net revenue made available by the railroad enterprise to pay for overhead, improvement and dividends. The sources of net railway operating income are railraod revenues less taxes and less rental payments for use of other companies' equipment and trackage, plus rental receipts for equipment and facilities used

TABLE II

FINANCIAL CONDITIONS OF THE NORTHEASTERN BANKRUPT RAILROADS IN YEARS PRECEDING BANKRUPTCY (THOUSANDS OF DOLLARS)

Account	3 Years Before	2 Years Before	1 Year Before	Year of Bankruptcy
Ann Arbor Railroad (1973)				
Total Current Assets	3,321	3,261	3,277	5,221
Total Current Liabilities	3,487	3,172	3,404	7,210
Operating Ratio	85.05%	91.98%	93.07%	97.88%
Net Rwy. Operating Income	-178	-921	-1.105	-1,867
Ordinary Company Income	-821	-1,665	-1,958	-2,861
Boston & Maine Railroad (1970)				
Total Current Assets	13,033	13,687	14,964	18,633
Total Current Liabilities	19,974	22,692	27,257	16,407
Operating Ratio	82.11%	88.33%	84.40%	88.93%
Net Rwy. Operating Income	695	-1,224	-2,541	-6,509
Ordinary Company Income	-3,417	-5,401	-6,391	-10,781
Central Railroad of New Jersey (1967)				
Total Current Assets	12,070	11,210	11,687	10,163
Total Current Liabilities	12,498	12,808	17,447	13,665
Operating Ratio	93.54%	87.41%	90.83%	95.73%
Net Rwy. Operating Income	-5,678	-3,240	-4,853	-9,381
Ordinary Company Income	-8,254	-6,665	-7,451	-13,616
Erie Lackawanna Railroad (1972)				
Total Current Assets	42,948	41,236	36,556	42,639
Total Current Liabilities	45,784	56,667	52,044	45,410
Operating Ratio	79.46%	80.93%	79.04%	84.66%
Net Rwy. Operating Income	9,049	-332	8,991	-7,744
Ordinary Company Income	1,259	-8,948	-1,428	-18,191
Lehigh Valley Railroad (1970)				
Total Current Assets	10,854	11,075	10,868	14,440
Total Current Liabilities	16,226	14,433	10,092	12,292
Operating Ratio	85.82%	87.39%	83.92%	89.00%
Net Rwy. Operating Income	-2,613	-4,445	-3,298	-6,355
Ordinary Company Income	-3,738	-5,969	-5,224	-9,509
Penn Central Railroad (1970)				
Total Current Assets	2	375,818	477,815	523,531
Total Current Liabilities	2	435,121	483,455	413,638
Operating Ratio	2	83.62%	85.60%	92.08%
Net Rwy. Operating Income	2	-26,993	-67,821	-236,518
Ordinary Company Income	2	-2,773	-82,814	-235,739

TABLE II (Continued)

Account	3 Years Before	2 Years Before	1 Year Before	Year of Bankruptcy
Reading Railroad (1971)				
Total Current Assets	26,282	26,360	24,014	26,177
Total Current Liabilities	28,857	31,780	32,507	29,453
Operating Ratio	86.32%	85.48%	85.97%	87.14%
Net Rwy. Operating Income	-203	-603	-2,309	-5,776
Ordinary Company Income	-3,793	-3,320	-5,626	-11,749

[1]Based upon data published by the Interstate Commerce Commission in _Annual Reports on Transport Statistics in the United States_, Washington, D. C.

[2]The Pennsylvania Railroad and the New York Central Railroad Merged in 1968; 1967 figures are not meaningful.

TABLE III

FINANCIAL CONDITIONS OF THE ROCK ISLAND AND KATY RAILROADS: 1971-74[1]
(THOUSANDS OF DOLLARS)

Account	1971	1972	1973	1974
	Chicago, Rock Island & Pacific (6,379)[2]			
Total Current Assets	48,563	45,618	47,469	59,066
Total Current Liabilities	59,258	59,680	70,393	83,608
Net Rwy. Operating Income	-4,315	-5,503	-18,185	-22,182
Ordinary Company Income	-6,415	-5,855	-19,281	-23,097
Operating Ratio	79.60%	80.68%	81.80%	82.95%
Rate of Return on Net Investment	deficit	deficit	deficit	deficit
	Missouri-Kansas-Texas (1,904)			
Total Current Assets	11,948	11,400	14,427	14,116
Total Current Liabilities	16,475	17,827	20,686	23,076
Net Rwy. Operating Income	1,208	-969	-2,015	-1,583
Ordinary Company Income	21	-2,560	-3,733	-2,560
Operating Ratio	72.92%	75.24%	74.55%	76.85%
Rate of Return on Net Investment	0.64%	deficit	deficit	deficit

[1]Based upon data published by the Interstate Commerce Commission in _Annual Reports on Transport Statistics in the United States_, Washington, D. C.

[2]Numbers in parentheses denote miles of road owned by the company on December 31, 1974.

by other companies. Ordinary company income is the final net income left after all expenses are paid. Account is taken for income and expenses not directly related to transportation and unavoidable, annual interest charges are subtracted. Net railway operating income and ordinary company income became increasingly negative for the railroads shown in Table II as bankruptcy approaches. Current liabilities exceed current assets, the operating ratio is gradually increasing to over 80 percent, and the net railway operating income and ordinary company income are both negative for the Rick Island in years prior to bankruptcy. The Katy also has current liabilities that exceed current assets, an increasing operating ratio and negative income balances. This similarity of the financial condition of the Katy to the bankrupt Rock Island and Northeastern railroads would indicate that the Katy is also nearing bankruptcy.

The likely result of railroad company bankruptcy is that the most profitable line segments will be sold to other railroads. Other line segments, including many branch lines and light density lines, will likely be found unprofitable and abandoned. An example of this occurred recently when the Interstate Commerce Commission called an emergency meeting of the major western railroads, on March 17-18, 1975, to work on a suggested partitioning of Rock Island lines which would divide the rail routes into operable segments to be taken over by other railroads. Table IV shows the proposed temporary service provided by other railroads. A look at Table IV shows that several routes in Oklahoma would not be serviced. Therefore, the end result of railroad bankruptcy likely will be the abandonment of lines not considered financially desirable by other railroads. The cost of operation and rehabilitation will, of course, affect the decision.

TABLE IV

PROFILE OF TEMPORARY SERVICE OVER ROCK ISLAND LINES BY OTHER CARRIERS*

Line	Local Centers	Assuming Railroad
Kansas City-Tucumcari Mainline	Liberal, Guymon	Southern Pacific or Santa Fe (Contested)
Liberal-Morse-Wilco Branch	Hardesty	Santa Fe
Herington-El Reno-Ft. Worth Mainline		
1. Wellington, Kan.-Enid	Medford, Enid	Santa Fe
2. Enid-El Reno	Kingfisher	Frisco
3. El Reno-Chickasha	Union, Minco, Pocasset	No service proposed
4. Chickasha-Beckett (Sunray)	Duncan	Frisco
5. Beckett-Waurika-South	Comanche, Addington, Terral	No service proposed
Enid-Ponca City Branch	Garber, Billings, Tonkawa	Santa Fe
Enid-Alva Branch	Burlington, Ingersoll	No service proposed
Enid-Warren Branch	Ringwood	Frisco
El Reno-Amarillo-Tucumcari Mainline		
1. El Reno-Weatherford	Calumet, Geary, Bridgeport	Frisco
2. Weatherford-Clinton	Indianapolis	No service proposed
3. Clinton-Elk City	Foss, Canute	Frisco
4. Elk City-Norrick	Sayre, Texola	No service proposed
Homestead Branch		
1. Geary-O'Keene	Watonga, Hitchcock	Frisco
2. O'Keene-Homestead		No service proposed

TABLE IV (Continued)

Line	Local Centers	Assuming Railroad
Chickasha-Mangum Branch		
1. Chickasha-Hobart	Anadarko, Carnegie, Gotebo	Frisco
2. Hobart-Lone Wolf		No service proposed
3. Lone Wolf-Mangum	Granite	Santa Fe
Anadarko-Waurika		
1. Anadarko-Richards	Apache	No service proposed
2. Richards-Waurika	Lawton, Walters, Hastings	Frisco
Memphis-Little Rock-OKC-El Reno Mainline		
1. Bonneville, Ark.-Hartshorne	Howe, Red Oak, Wilburton	Frisco
2. Hartshorne-OKC	McAlester, Holdenville, Shawnee	Missouri-Kansas-Texas
3. OKC Switching		Frisco, Santa Fe, Katy
4. OKC-El Reno	Yukon	Frisco

*In the event the Interstate Commerce Commission orders solvent railroads to temporarily operate over Rock Island lines, line segments will be apportioned to other railroads in accordance with this table, reflecting agreement by railroads on March 18, 1975.

Rail Preservation Policy

The Interstate Commerce Commission (ICC) has regulated rail abandonment proceedings since 1920. In the past, the financial burden of an unprofitable rail line fell on the railroad companies. The financial collapse of the major railroads serving the Northeastern area of the United States forced a change in the federal government's attitude toward rail regulation. The Regional Rail Reorganization Act of 1973 (P.L. 93-236) was enacted to remedy the problem of Northeastern railroad failures. The 1973 Act moved the financial responsibility for an unprofitable rail line from the operating railroad to the railroad user in the Northeastern states. The Railroad Revitalization and Regulatory Reform Act of 1976 (P.L. 94-210) extended the provisions of the 1973 Act to the entire nation. In addition, the 1976 Act streamlined abandonment procedures. The effect of these new laws may be an increase in abandonment proceedings in rural areas.

Past ICC Regulation of Abandonment

Prior to the financial failure of the Northeastern railroads, the regulation of rail line abandonment emphasized the local public interest. Conflicts were resolved on the basis of the "balancing of interests" principle.[3] This principle sought a balance between the potential losses of the railroad if operations on a line segment continued and the potential losses suffered by the local public if the line segment was closed. The railroad was obligated to show that the cost of operating a line segment was greater than revenues generated by that segment. The local public could prevent abandonment of a line segment by showing they could and would generate enough traffic to cover operating deficits in the near future. If a line segment remained open, the owner railroad had complete financial responsibility. The "balancing of interests" principle was overridden only when continued operation of a rail segment threatened the financial solvency of the entire railroad.

Regional Rail Reorganization Act of 1973

The bankruptcy of the Penn Central Transportation Company in 1970, and five other northeastern railroads soon after, left the Northeastern United States without reliable rail transportation. The trustees of the bankrupt companies reported that each of the railroads involved suffered from a basic shortage of income which would prevent covering operating expenses and debts. One suggested reason for the railroads' inability to generate income was the regulatory inhibitations to abandonment of unprofitable line. The Regional Rail Reorganization Act of 1973 provided for the reorganization of the Northeastern railroads into the Consolidated Rail Corporation (ConRail). Lines designated as non-essential were to be abandoned if railroad users, communities, and state failed to purchase the line or subsidize operations. That is, the railroad would no longer be financially responsible for a line segment approved for abandonment.

The 1973 Act included provisions for federal aid to states and local communities attempting to subsidize lines being abandoned. Federal subsidies were made available to continue rail service on lines not considered essential to the overall Northeastern rail needs, but considered valuable to state and local interests. The subsidies could be used to contract with Con Rail or other railroads for rail service and to improve and maintain rail properties. In addition, loans are possible to states and local transportation authorities for purchase of rail properties not in the regional system plan. Loans and loan guarantees could also be made for repair and restoration of properties purchased. Subsidies and loans were limited to 70 percent of the cost of continuation or purchase.

Rail Revitalization and Regulatory Reform Act of 1976

The provisions on federal aid to states and local communities attempting to maintain rail service on lines to be abandoned in the 1973 Act applied only to the Northeastern region of the United States. The Rail Revitalization and Regulatory Reform Act of 1976 extended similar provisions to the rest of the nation. The 1976 Act authorized $360 million in federal funds, over the next five years, for financial assistance to specific rail line segments given Interstate Commerce Commission approval. No state matching funds are required in the first year of the program. State or local communities match aid funds in the proportions of 10 percent the second year, 20 percent the third year, and 30 percent the remaining two years.

Rail freight assistance programs which qualify for federal funding include:

a) subsidies to continue rail operations;

b) purchase and operation of a railroad line to provide future rail service;

c) rehabilitation and improvement of rail properties on a line; and

d) adjustment assistance to those losing rail service.[4]

The 1976 Act also made abandonment procedures faster and more precise. However, the public has a substantially longer notice of intention to abandon a line segment. The time table for an abandonment case not challenged by the public is shown in Table V. Each railroad must publish a diagram of the transportation system operated by the company. A line segment must be described on the diagram as "potentially subject to abandonment" at least four months before application to abandon is filed. The application must be filed with the Interstate Commerce Commission at least 60 days before the intended action. Any proposed financial assistance must be made by state or local groups within 30 days of approval. If the Interstate Commerce Commission finds that satisfactory financial assistance is provided the abandonment approval may be postponed. If not, the abandonment may take place 120 days after approval. Thus, country grain elevator owners and managers have up to ten months to adjust to abandonment when no financial assistance is provided to maintain rail service.

Country Grain Elevator Adjustments to Rail Abandonment

Country grain elevators in Oklahoma have relied in the past on rail transportation to move a large portion of the wheat crop to domestic and export markets. Previous sections of this chapter have shown that track is being abandoned in Oklahoma, that more track may be considered for abandonment in the future, and that two major railroads serving the state are in serious financial condition. Oklahoma country grain elevator owners and managers facing abandonment must look toward

TABLE V

TIMETABLE FOR AN ABANDONMENT CASE
NOT CHALLENGED BY THE PUBLIC

Event	Time	Cumulative Time
Line Diagrammed as "Potentially Subject to Abandonment"	At least 4 mo. Before Application	0 mo.
Abandonment Application		4 mo.
Abandonment Approval	60 day waiting period	6 mo.
Proposed Financial Assistance	Within 30 days of approval	7 mo.
Abandonment if No Financial Assistance is Proposed	120 days after approval	10 mo.

*From Current Report, Oklahoma State University, No. 824.

other modes of transportation. Basically, country elevators in Oklahoma may:

1) revert to some type of truck operation. Most country grain elevators currently own few trucks and no grain trailers are leased in Oklahoma. For-hire trucks are used only on a limited basis by most country grain elevators. However, with the railroad gone, the elevator may find that owning, leasing or hiring grain trucks may be the best alternative;
2) make rail shipping or receiving, or other operating arrangements with an elevator located on another line not likely to be abandoned. This alternative may be desirable in the case of a country grain elevator with several stations under its control. Wheat from a station located on an abandoned branch line may be trucked to another station on a main line;
3) pay higher rail rates or a lump sum subsidy in order to retain rail service. This alternative assumes that: (a) the total amount of increased rail payments are less than the next least costly transportation alternative solution and (b) the amount of increased revenue from all shippers on the line is sufficient to attract continued service; or
4) contribute to the purchase of part or all of the line to be abandoned for operation as a short line railroad. This alternative may be feasible when other shippers on the line segment being abandoned can effectively organize a shipper association. As with the third alternative, an elevator owner could only contribute an amount no greater than the cost of switching to the next best alternative transportation solution. The

total association cost may be defrayed by obtaining operating subsidies provided for in the Railroad Revitalization and Regulatory Reform Act of 1976. Federal funds obtained under this Act may be used to subsidize operations, purchase a rail segment, rehabilitate track, or adjust to the loss of rail.

Research Objectives

The purpose of the research presented herein is to design a systematic approach to guide the elevator owner and manager in the optimal selection of available transportation alternatives. Specific objectives of this study are:

1) to develop an operational procedure capable of guiding country grain elevator managers in selection of optimal long run adjustments in transportation;
2) to develop a procedure to measure the magnitude of contribution a country grain elevator could afford to pay in an effort to retain rail service, purchase a short line, or borrow federal funds; and
3) to demonstrate the techniques developed by determining the optimal long run adjustment in transportation for a country grain elevator currently operating in northwest Oklahoma.

Literature Review

Literature available on alternative transportation modes for country grain elevators is somewhat limited. However, several recent studies were influential in developing the format for this project.

A Ph.D. dissertation by Yates[5] analyzed the changing patterns of wheat movements between the local elevator and the final market. Yates concluded that the extensive employment of trucks had altered the formerly rail dominated pattern of wheat movement. The study also found that the railroad was, in some cases, being by-passed as a transportation agent and that the terminal market was being omitted in the wheat shipment pattern.

Baumel[6] presented a worksheet designed to provide a systematic procedure to make decisions on owning or buying grain transportation. The worksheet dealt with the economics of (1) leasing covered hopper cars versus shipping in boxcars, (2) leasing versus buying hopper cars, and (3) owning versus leasing trucks.

A study by Dahl and Martin[7] examined the influence of multiple-car rail rates on grain marketing patterns and country elevators. The study was conducted through a survey of multiple-car loading elevators and subterminals in southern Minnesota. The study concluded that multiple-car rates are a move toward a more efficient grain transportation system where the rate structure is based on service costs.

Easter and Nevine[8] studied the cost of owning grain trucks in Minnesota. The study developed cost budgets for two model firms to accurately estimate the total cost of owning trucks. The two model firms differed from one another by the number of trucks owned. The study concluded that high utilization levels keep trucks competitive with railroads, particularly for short hauls.

FOOTNOTES

[1]United States Interstate Commerce Commission, *Profile Listing of Selected Rail Abandonment Cases* (Washington, 1976).

[2]*Rail Line Clearances Including Weight Limitations of Railroads in the United States, Canada, and Mexico* (New York, 1976).

[3]Marc A. Johnson and Gary M. Mennem, "Oklahoma Railroads and a New Role for the State and Local Communities," *Current Farm Economics* Vol. 28, No. 2 (1975), p. 15.

[4]Marc A. Johnson and Gary M. Mennem, "The Railroad Revitalization and Regulatory Reform Act of 1976: Implications for Oklahoma," *Oklahoma State University Current Report*, No. 824 (Stillwater, 1976), p. 3.

[5]Tom W. Yates, "Some Economic Effects of Motor Trucks Upon the Movement of Wheat from Country Elevators" (Unpublished Ph.D. dissertation, Oklahoma State University, 1963).

[6]C. Phillip Baumel, "Should I Rent or Buy Transportation Equipment," *Proceedings of a Workshop on Buying or Leasing Grain Transportation Equipment* (Ames, Iowa, June 8, 1971), pp. 47-59.

[7]Reynold Dahl and Michael Martin, "Multiple-Car Rates--Their Impact on Grain Transport," *Minnesota Agricultural Economist*, No. 563 (St. Paul, January, 1975).

[8]K. William Easter and Rolland J. Nevine, "Grain Trucking in Minnesota--What it Costs in Region 6E," *Minnesota Agricultural Economist*, No. 569 (St. Paul, July, 1975).

CHAPTER II

THEORY

This study is concerned with determining a systematic method of evaluating alternative modes of transportation for country grain elevators. Theoretically, country grain elevators operate under market conditions that most resemble perfect competition. One of these market conditions is that the selling price of wheat is basically the export wheat price less transportation and handling costs. Since the country grain elevators' selling price is based on the export rate, the objective function for this study is to minimize the cost of shipping wheat. Once the objective function has been chosen, cost functions and decision criteria for each mode of transportation may be developed to minimize costs. Finally, the minimization objective function will be implemented through a linear programming format.

Perfect Competition

Assuming that there is no imperfection of the market in the sale of transport services due to location, country grain elevators operate under market conditions that most resemble perfect competition. They are that:

1) every economic agent is so small, relative to the total market, that is cannot exert a perceptible influence on price;
2) the product of the seller in the market must be identical to

the product of every other seller, i.e., there is no differentiation of product;

3) all resources are perfectly mobile, that is, there is free entry and exit in the market; and

4) consumers, producers, and resource owners in the market must possess perfect knowledge.[1]

Oklahoma country grain elevators meet the first two assumptions easily. The third assumption, regarding free entry and exit, is difficult to meet because of the high fixed costs of storage facilities. The final assumption of perfect knowledge is approximated for the grain industry by reliable access to market information.

The individual producer in a perfectly competitive market faces a horizontal demand curve. Regardless of the quantity sold, all units are paid the same price when the market is in equilibrium. The marginal revenue (MR) of each new unit of output is equal to the selling price (P). Figure 2 presents equilibrium between supply (S) and demand (D) in a perfectly competitive market and for an individual firm within that market.

Marginal cost (MC) is defined as the change in total cost attributable to a one unit change in output. In the short run time period there is a fixed cost that does not change with the level of output. Marginal cost in the short run, then, is equal to the change in variable cost of production associated with a one unit change in output. In the short run a perfectly competitive firm will maximize profit or minimize loss at the point where MC = D = MR. The long run analysis for a perfect competitor is LMC = D = MR, where LMC is the long run marginal cost.

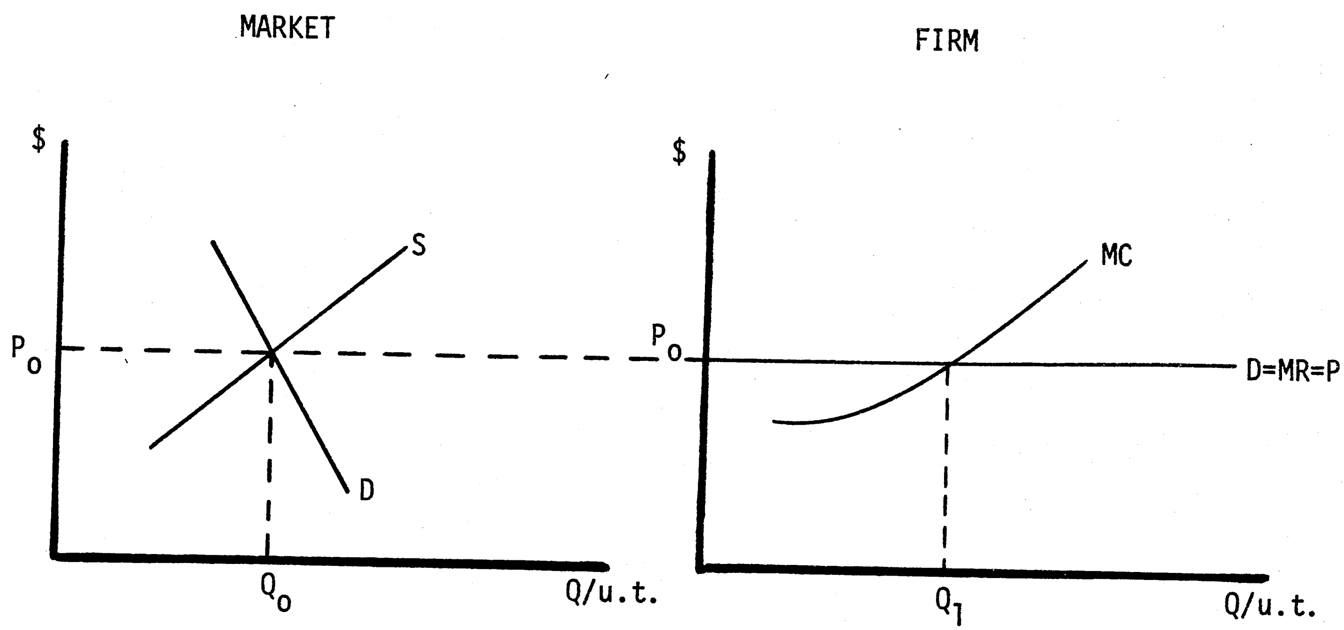

Figure 2. Equilibrium Conditions in Perfect Competition

Objective Function

The basic decision criterion of many firms in making investment decisions is that the net present value of the project is nonnegative, i.e., (NPV) ≥ 0. To find the NPV of a proposed project, assume that:

1) d = discount rate employed;

2) $0_0, 0_1, 0_2, \ldots, 0_n$ = cash outflows at times 0, 1, 2, ..., n; and

3) $I_1, I_2, \ldots, I_n$ = cash inflows at times 1, 2, ..., n.

Then, the equation for finding NPV is[2]

$$NPV = \left[\frac{I_1}{(1+d)^1} + \frac{I_2}{(1+d)^2} + \ldots + \frac{I_n}{(1+d)^n}\right] - \left[0_0 + \frac{0_1}{(1+d)^1} + \frac{0_2}{(1+d)^2} + \ldots + \frac{0_3}{(1+d)^n}\right].$$

The above criterion uses a single discount rate and assumes that the intermediate cash inflows generated by the project during its life will be reinvested at a rate of return equal to the discount rate employed. Intermediate cash outflows are also financed at this rate. The length of the time horizon will be instrumental in determining the relevant discount rate and the necessary replacement costs.

The decision criterion for this study, however, is a variation of the NPV formula. The market price for wheat is assumed to be constant. Prices at different markets differ only by the bid spread. The bid spread is equal to the transportation and marketing cost involved. Revenues may then be considered constant if the bid spread is included on the cost side. Thus, the objective of this research is to minimize the net present cost (NPC) of shipping wheat from a country grain elevator. The equation is:

$$NPC = O_0 + \frac{O_1}{(1+d)^1} + \frac{O_2}{(1+d)^2} + \ldots + \frac{O_n}{(1+d)^n} ,$$

which is the latter portion of the NPV equation.

Cost Functions

Wheat is shipped from country grain elevators by two basic transportation carriers, (1) railroad and (2) truck. Thus, the total cost function for a country grain elevator is

Total Cost = Total Cost of Railroad + Total Cost of Trucks.

From the country grain elevators' point of view, the total cost of shipping wheat by railroad to the export market is simply

Total Cost = per bushel cost x # bushels.

Therefore, the total cost of railroad shipment is a variable cost.

The total cost of trucking is more complex. In fact, the cost of using a truck is dependent on the type of ownership arrangement involved. Grain trucks may be owned, leased, or hired. The total cost of trucks may then be expressed as

Total Cost of Trucks = Total Cost of Owning Trucks + Total Cost of Leasing Trucks + Total Cost of Hiring Trucks.

The total cost of trucking may also be separated into variable and fixed cost components. For instance, the total cost of owning a truck involves the variable costs (of fuel, maintenance, etc.) of operating the truck, plus the fixed cost of ownership (of the tractor and trailer, insurance, etc.). Leasing grain trucks in Oklahoma involves some fixed costs, because by tradition, grain trailers are not leased in the state. The total cost of leasing trucks then is the variable cost of operating the truck, plus the fixed costs of owning the trailer. The total cost of owning or leasing a truck may then be expressed as

Total Cost = Fixed Cost of Ownership + Variable Cost of Operation.

The total cost of hiring trucks is the per bushel charge for hauling wheat and may be expressed as

Total Cost = per bushel cost x # of bushels.

The total cost of hiring is therefore a variable cost.

The degree to which the cost of a durable input such as a tractor or trailer is unavoidable depends upon the fixity of that input. A fixed input is defined as one whose quantity cannot be readily changed when market conditions indicate that an immediate change in output is desirable.[3] The ownership cost associated with a durable input would thus be defined as fixed when that cost cannot be avoided by changing the level of output. The purchase price of a truck unit must be paid whether it is used to haul wheat or not.

In addition, there is no distinct demarcation between the time that a particular durable input is a fixed cost and when the input becomes a variable cost. W. A. Lewis has studied the anatomy of fixed costs and proposes these unavoidable costs fall into several categories. Of fixed costs, Lewis says that:

1) some are unavoidable in the short run but not in the long run;
2) some are unavoidable for small but not for large changes in

output; and

3) some are unavoidalbe in all senses.[4]

Ferguson and Maurice define the long run as that period of time in which all inputs are variable.[5] According to Lewis, not all costs become variable and therefore avoidable. Thus, a cost function where durable inputs are of varying degrees of fixity is relevant.

A realistic assumption to make when discussing the fixed costs of operating trucks is that each tractor and trailer has a limited technical life span (T). The length of the technical life span in turn determines the length of the time horizon. A realistic time horizon (L) is necessary to determine relevant replacement and depreciation costs. If the time horizon is finite (as it is when T = L) the total annual cost of owning, leasing, or hiring a truck is

$$TAC = a + bx,$$

where:

TAC = Total annual cost;

a = discounted annual fixed cost of owning or leasing a truck;

b = the variable cost per bushel of shipping wheat;

x = the number of bushels of wheat shipped annually.

The total annual cost of using hired trucks has no intercept term because there are no fixed costs involved.

The total annual cost of shipping wheat for a country grain elevator may then be expressed as

$$TAC = (b_R X_R) + (a_O + b_O X_O) + (a_L + b_L X_L) + (b_H X_H)$$

where subscripts R, O, L, and H refer to railroad, owned trucks, leased trucks and hired trucks, respectively.

Decision Criteria

The objective of the model in this study is to minimize the net present cost (NPC) of shipping wheat from a country grain elevator, subject to the production function constraint. Kuhn-Tucker conditions are derived to allow for linear programming corner solutions, where the result may be the use of only one mode of transportation. Mathematically, these conditions are derived by using the Lagrangian form

$$Z = (b_R X_R) + (a_0 + b_0 X_0) + (a_L + b_L X_L) + (b_H X_H) \\ - \lambda[f(X_R, X_0, X_L, X_H) - y],$$

where λ is the Lagrangian multiplier and y is the shipment of wheat from a country grain elevator. Taking the partial derivatives of Z with respect to X_R, X_0, X_L, X_H and λ gives the marginal productivity conditions (first column)

$$\frac{\partial Z}{\partial X_R} = b_R - \lambda f_R \geq 0 \qquad X_R \geq 0 \qquad X_R \frac{\partial Z}{\partial X_R} = 0$$

$$\frac{\partial Z}{\partial X_0} = b_0 - \lambda f_0 \geq 0 \qquad X_0 \geq 0 \qquad X_0 \frac{\partial Z}{\partial X_0} = 0$$

$$\frac{\partial Z}{\partial X_L} = b_L - \lambda f_L \geq 0 \qquad X_L \geq 0 \qquad X_L \frac{\partial Z}{\partial X_L} = 0$$

$$\frac{\partial Z}{\partial X_H} = b_H - \lambda f_H \geq 0 \qquad X_H \geq 0 \qquad X_H \frac{\partial Z}{\partial X_H} = 0$$

$$\frac{\partial H}{\partial \lambda} = f(X_R, X_0, X_L, X_H) - y \leq 0 \qquad \lambda \geq 0 \qquad \lambda \frac{\partial Z}{\partial \lambda} = 0.$$

An additional constraint requiring nonnegativity of all inputs and the output (second column), and a complementary-slackness condition (third column) are also given.[6] The marginal conditions require that the variable cost of an input be equal to or greater than the marginal revenue associated with that input. The marginal condition of $\frac{\partial Z}{\partial \lambda}$ requires that the total quantity shipped by all modes of transportation in the solution be no greater than the total amount shipped by the country grain elevator. The nonnegativity condition prevents the possibility of negative production. The purpose of the complementary-slackness condition is to ensure that for each mode of transportation in the optimal solution either the marginal condition holds as an equality, or that the mode of transportation in question takes a zero value, or both.

Linear Programming

The model to be developed in this study will be implemented through a linear programming format. The use of linear programming allows the handling of multiple budgets in a problem rather than solving each budget singularly. Linear programming emphasizes "activities" rather than particular products and factors.[7] An activity is defined as a thing being produced, an enterprise undertaken, or a method of production used.[8] In linear programming a particular product may be produced by several different activities, each using different factor-input ratios. Each activity requires a specific proportion of various resources to produce one unit of that activity. A more detailed explanation of the principles of linear programming may be found in Agrawal and Heady.[9]

Mathematically, the linear programming model will be to minimize

$$NPC = \sum_{j=1}^{N} C_j X_j$$

subject to

$$\sum_{j=1}^{K} A_{ij}X_j \quad = \text{amount of wheat sold during harvest}$$

$i = 1, 2, \ldots, m$

$$\sum_{j=K+1}^{L} A_{ij}X_j \quad = \text{amount of wheat shipped during harvest}$$

$i = 1, 2, \ldots, m$

$$\sum_{j=L+1}^{N} A_{ij}X_j \quad = \text{amount of wheat shipped the rest of the year}$$

$i = 1, 2, \ldots, m$

where

X_j = the number of units used by the j^{th} activity;

C_j = the NPC per unit of the j^{th} activity; and

A_{ij} = the number of bushels shipped by one unit of the j^{th} activity under the i^{th} constraint.

The above constraints i = 1, 2, ..., m will require the model to sell specific amounts of wheat during harvest, ship certain amounts of wheat during harvest, and ship the remaining wheat in storage during the rest of the year. Additional constraints on capital limitations, the number of owned and leased trucks and the availability of rail cars or hired trucks may be added as needed. The linear program will then select the most efficient mode to move that wheat.

A mixed integer program is used in this study to determine the optimal number of owned and leased trucks in the optimal solutions of the model, subject to ownership constraints. The mixed integer programming format differs in that some activities in the final solution must be whole numbers (integers). Thus, the linear programming assumption of divisibility of activities and resources is relaxed in the case of owned or leased trucks. The mixed integer program will select either a whole truck or no truck at all.

The linear programming model used in this study makes several assumptions based on perfect competition. The model assumes that the activity cost of using a mode of transportation remains constant throughout the year, regardless of how much the country grain elevator utilizes that mode. The model also assumes that the country grain elevator cannot influence wheat margins by the number of bushels of wheat the elevator sells. Most important of all, the model assumes that the goal of the elevator manager is to minimize net present cost.

FOOTNOTES

[1]C. E. Ferguson and S. Charles Maurice, Economic Analysis (Homewood, 1970), pp. 160-161.

[2]James T. S. Porterfield, Investment Decisions and Capital Costs (Englewood Cliffs, 1965), p. 30.

[3]Ferguson and Maurice, p. 102.

[4]W. A. Lewis, "Fixed Costs," Transport (Baltimore, 1968) pp. 61-62.

[5]Ferguson and Maurice, p. 102.

[6]Alpha C. Chiang, Fundamental Methods of Mathematical Economics (St. Louis, 1974), pp. 704-713.

[7]Thomas Naylor and John M. Vernon, Microeconomics and Decision Models of the Firm (Chicago, 1974), p. 231.

[8]R. C. Agrawal and Earl O. Heady, Operation Research Methods for Agricultural Decisions (Ames, 1972), p. 33.

[9]Ibid., pp. 26-78.

CHAPTER III

PROCEDURE

The decision-making tool to be developed in this study is designed for use by a country grain elevator in Oklahoma. The decision-making tool will be implemented by use of a linear programming model. The Mathematical Programming System--Extended (MPSX) provides the means to apply the linear programming technique.[1] The MPSX system is efficient for evaluating the costliness of activities and shadow prices of resources. It provides information on the sensitivity of the activities relative to price changes. In addition, the MPSX system allows easy manipulation of activities or resources to determine their effect on the optimal transportation solution.

The purpose of this chapter is to develop a procedure for construction of the coefficients that will go into the linear programming model. The steps of the procedure are: (1) determine what activities (columns) should be included in the model, (2) determine what restrictions that affect transportation should be included in the model, (3) determine cost equations for each activity, (4) design a questionnaire to collect basic information from a country grain elevator, (5) determine applicable rail rates, (6) determine applicable truck rates and develop owned and leased truck budgets, and (7) develop a mixed integer programming routine to select the optimal number of trucks to be owned and leased.

Activity Determination

An activity, as defined in Chapter II, is a thing being produced, an enterprise undertaken, or a method of production used. In terms of this study, an activity is a specific mode of transportation carrying wheat from a specific station to a specific destination. The number of modes of transportation available for use at any specific station is determined by the stations' location, financial and physical limitations. Country grain elevators having more than one station may have more than one activity for each mode of transportation if input costs at each of the stations differ. The shipping destinations of wheat from a specific elevator can be determined by examining current practices and future expectations.

Restriction Determination

Country grain elevators are hampered in minimizing the cost of transportation by limitations or restrictions placed on activities from inside and outside the firm. The MPSX system allows the country grain elevator to restrict activities by means of right hand sides (RHS). Typical restrictions from inside the firm are loading limitations, financial limitations and manager preference. Outside restrictions may take the form of unavailable modes of transportation during certain periods of the year or the selling patterns of farmers utilizing the country grain elevators' storage space. Restrictions that apply to a specific elevator may be determined by reviewing storage capacity, rail and truck information and shipping patterns. Further restrictions may come from interviews of the elevator manager.

Activity Cost Determination

The equations used to determine activity costs in this study can be found in Table XIII in Appendix B. The basic formulas for each type of activity are given in Table VI. The procedure for determining the components of rail and truck costs will be discussed in coming sections on rail and truck rates. Two items in Table VI are not discussed in the rail and truck cost procedures. They are: (1) the bid spread between the Houston export bid price and the local bid price and (2) activity time. A brief discussion of each will follow.

Bid Spread

The purpose of the bid spread is to account for the difference in the selling price of wheat at different locations. Since the Houston export price is used as the base price, the bid price at Houston export is a zero cost when the country grain elevator sells for that price. When the country grain elevator sells at a terminal elevator away from Houston, the shipping cost may decrease, but the selling price will also be less. The difference between the Houston export price and the terminal elevator price is the bid spread and is a cost to the country grain elevator.

Activity Time

Each truck activity requires a specific amount of truck time to ship wheat. The truck time required by each truck activity is referred to as "activity time". Table XIV in Appendix B gives the truck time required for a truck to make a trip to and from a specific destination

TABLE VI

FORMULAS FOR ACTIVITY COST DETERMINATION

<u>Rail</u>

Total Cost = rail rate/bushel x # of bushels/activity

<u>Own Truck, Lease Truck</u>

Total Cost = [variable cost/hour of available truck use x activity time] + [bid spread/bushel* x 875 bushels/truckload]

<u>Hire Truck</u>

Total Cost = [applicable hire truck rate/bushel + bid spread/bushel*] x 875 bushels/truckload

<u>Own Truck-Rail, Lease Truck-Rail</u>

Total Cost = [variable cost/hour of available truck use x activity time] + [rail rate/bushel x 875 bushels/truckload]

<u>Hire Truck-Rail</u>

Total Cost = [applicable hire truck rate/bushel + rail rate/bushel] x 875 bushels/truckload

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*The bid spread for wheat delivered to Houston is zero. The bid spread is 26¢ at Catoosa and 36¢ at Enid.

for the model demonstration in Chapter IV. "Activity time" consists of three parts. They are: (1) loading, (2) driving, and (3) unloading. Information for the table may be obtained through interviews with the managers of both the country grain elevator and the terminal elevator receiving the shipment.

The Questionnaire

The questionnaire is a convenient method of collecting much of the basic information needed. The questionnaire used in this study to collect data for the model demonstration in Chapter IV can be found in Appendix A. Five major areas are covered in the questionnaire used in this study. They are: (1) organization information, (2) storage capacity, (3) rail information, (4) truck information, and (5) shipping information. A brief discussion of each area follows.

Organization Information

The purpose of this section is to record the names of all stations associated with the country grain elevator in question. The name and address of each station should be recorded for future reference. In addition, the name of the manager and the phone number of the main elevator should be included. The names and addresses of any terminal elevators with which the country grain elevator has a binding relationship should also be included in this section. These data may be used later to determine what stations to include in the model.

Storage Capacity

Information in this section is used to confirm the amount of storage capacity available to the country grain elevator. Items such as total storage capacity of the elevator, what portion of storage capacity is unavailable for use by wheat, and the storage capacity of each station should be included. These data may be used later to determine restrictions on the amount of wheat shipped from each station during harvest and non-harvest periods.

Rail Information

The purpose of this section of the questionnaire is to obtain information on the country grain elevators' rail loading facilities, rail rates and rail service. Items in this section include the names of railroads providing service, amount of service provided, the rail loading ability of the elevator, physical restrictions on the rail serving the elevator, quality of rail service, rail rates paid, and the availability of truck substitution. The data collected in this section may be used to determine restrictions on wheat shipments by rail and the cost of rail activities involved in the model.

Truck Information

This section of the questionnaire provides information on the country grain elevators' truck ownership costs, the types of trucks used by the elevator (owned, leased, or hired), the quality of service provided, and the elevators' truck loading facilities. Items in this section include the number of owned trucks, fixed and variable ownership costs, use of leased and hired trucks, and the truck loading ability of each station. Data collected in this section may be used in budgets for owned and leased trucks. Data from this section may also be used to determine current patterns of wheat shipment by truck.

Shipping Information

The purpose of this final section is to collect information on the amount of wheat shipped from each station by each available mode of transportation. Questions in this section also determine the length of the harvest period and the operating hours of the country grain elevator. Data collected in this section are used to determine shipping restrictions and number of hours of available truck time. Shipping information from this section also serves as a base to show how much adjustment will change the shipping pattern.

Rail Rate Determination

Applicalbe rail rates may be obtained from several sources. Rail rates currently in effect in Oklahoma come from Ex Parte 313, effective October 11, 1975. The rail rate may also be obtained by direct questioning of the elevator manager. Published rates may be consulted to derive rates for new routes.

Truck Cost Determination

Trucks* are available to a country grain elevator in three different ownership arrangements. Trucks may be: (1) owned,

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*In this study, a truck refers to a semi-trailer truck used for hauling wheat. Each truck unit will consist of one tractor and one trailer.

(2) leased, or (3) hired. Each ownership arrangement involves different fixed and variable costs. The procedure for determining the cost of each type of truck ownership arrangement follows.

Owned Truck

The procedure for determining the cost of owning a truck has three major steps. The first step is to build a budget reflecting the total fixed and variable costs of owning a grain truck. The second step is to determine the total number of hours that the truck will be available for use. The final step is to compute the average variable cost per hour of available truck time by using the results of the first two steps. A more detailed explanation of each step follows.

Owned Truck Budget

The budget used in this study defines the costs associated with owning a truck as either fixed or variable. Fixed costs, in this study, are recurring costs that must be paid whether the truck is used or not. Likewise, the size of variable costs depend on the level of truck use. The owned truck budget used in this study for the model demonstration in Chapter IV can be found in Table XV in Appendix B. A brief discussion of each of the components of the owned truck budget follows.

Fixed Costs. Items included as fixed costs in this study are the discounted annual payments for the tractor and trailer, licenses and permits, taxes, and insurance. The discounted annual payments for the tractor and trailer are based on a straight-line method of depreciation and a known rate of interest. Taxes included as fixed costs are for highway use, social security, and unemployment. Insurance included as fixed costs are workmens' compensation, health and medical, and revenue equipment. Information on fixed costs can be found in the financial books of the country grain elevator.

Variable Costs. Items included as variable costs in this study are fuel, oil, gaskets, filters, batteries, tires, maintenance and repair, and driver compensation. Fuel and oil are major use items that are continually being replaced. However, filters and gaskets, batteries, and tires are items that occur at irregular times and may best be grouped together for an average annual cost. Maintenance and repair includes scheduled maintenance and major repair, including labor. Driver compensation is the salary paid to the truck driver each year. As with fixed costs, variable cost information may be found in the country grain elevators' financial books.

Hours of Available Truck Use

Theoretically, trucks may be used almost constantly day and night. But realistically, a truck operated by a country grain elevator will normally be used during the elevators' regular work hours when used locally. Due to the nature of the wheat harvest, elevators are open later each day during the harvest period. Therefore, each year is divided into two time periods: (1) harvest and (2) rest of the year. Computation of hours of available truck use during the harvest period is simply

Total number of harvest days x number of hours of operations per day.

To compute the number of hours of available truck use for the rest of the year, the number of days of operation during the rest of the year must be adjusted. This is done by subtracting holidays, weekends, and days of harvest from the total number of days in the year. The total number of hours of available truck use during the rest of the year will then be

Total adjusted number of days in the rest of the year X Number of hours of operation per day.

The computation of hours of available truck use used in the model demonstration in Chapter IV can be found in Table XVI in Appendix B.

Average Variable Cost per Hour of Available Truck Use

The formula for finding average variable cost/per hour of available truck use is

AVC = Total Variable Cost ÷ Total Hours of Available Truck Time.

Leased Truck

The procedure for determining the cost of leasing a truck is much the same as the steps taken to determine the cost of owning a truck. The basic difference between owned and leased truck budgets is that the tractor is leased. The effect on fixed costs is that the fixed weekly lease payment replaces the discounted annual payments from owning the tractor. In addition, the fixed cost of licenses and the highway use tax are avoided by leasing rather than owning the tractor. The effect on variable cost is the addition of a per mile of use charge.

However, the cost of oil, filters, gaskets, grease, batteries, tires, maintenance and repair are avoided by leasing the tractor. The hours of available truck use and the formula for average variable cost per hour of available truck use remain unchanged. The leased truck budget used in this study for the model demonstration in Chapter IV can be found in Table XVII in Appendix B.

Hired Truck

Hired truck rates for agricultural commodities are unregulated. As such, it is difficult to isolate specific rates that are followed consistently. The going rate to a specific destination is dependent upon the level of competition among trucking enterprises and competition from other modes of transportation. Other factors, such as the opportunity for backhauls, also affect hire truck rates. Under these conditions, hired truck rates may be estimated after interviewing local haulers and the country grain elevator manager. The hired truck budgets used in this study for the model demonstration in Chapter IV can be found in Table XVIII in Appendix B.

Truck-Rail

In some instances the local country grain elevator may find it practical to truck wheat to a nearby elevator to be loaded on to rail cars. The cost of such an activity is simply the cost of trucking plus the cost of rail. Procedures described in the preceding sections may be followed to obtain the proper costs.

Optimal Truck Selection

The MPSX system must be modified to insure that trucks are selected as whole units. Obviously the firm cannot own or lease a fraction of a truck. To insure that the programming model selects whole truck units, a mixed integer programming routine is utilized. The mixed integer programming routine accomplishes two things. They are: (1) trucks are selected as whole units and (2) a truck used in one period will be used in all periods in that year. The initial tableau of coefficients used in this study for the model demonstration in Chapter IV may be found in Table XIX in Appendix C.

Three pieces of information are needed to initiate the mixed integer programming routine. They are: (1) number of hours of truck time each activity uses, (2) the minimum number of hours per period a truck must be used to make owning or leasing of trucks economically desirable, and (3) the maximum number of hours a truck may be used in a period. Procedures to determine the truck time used by each activity and the maximum hours of time available from using one truck have been discussed in previous sections of this chapter. The minimum number of hours of truck time use that justifies owning or leasing a truck may be found by determining the breakeven point between owning or leasing, and the hiring of a truck. The procedure used in this study to determine minimum truck hour use for the model demonstration in Chapter IV may be found in Table XX in Appendix C.

FOOTNOTES

[1]James D. Libbin, Charles A. Moorhead, and Heil R. Martin, Jr., *A User's Guide to the IBM MPSX Linear Programming Package, Part I -- Small Models* (Urbana-Champaign, Ill., 1973), pp. 1-37.

CHAPTER IV

MODEL DEMONSTRATION

The procedures developed in Chapter III explained how to formulate the coefficients used in the model developed in the study. The procedures from Chapter III may now be applied in a demonstration of the mixed integer programming model. To demonstrate the model, it was decided to select an existing country grain elevator operating on the Rock Island rail line. The basic linear programming modes is varied by changing the constraint on owned and leased trucks. Owned and leased trucks are: (1) unlimited in number and (2) limited by capital investment in trucks. The availability of railroad is gradually removed from the model under each circumstance to determine the cost to the country grain elevator associated with the removal of the rail alternative. This chapter will discuss the optimal solution of each model variation, the effect on the current shipping pattern and the sensitivity of the optimal solution to change.

Demonstration Elevator

Elevator Description

The country grain elevator selected for demonstrating the linear programming model is located in Okeene, Oklahoma. The elevator also has stations located in Homestead, Hitchcock and Loyal. The Okeene station (station #1) is served by the main line of the St. Louis-San Francisco railroad and also by a branch line of the Rock Island railroad. The railroad serving the Homestead station (station #2) is a dead-end branch line of the Rock Island railroad. The Hitchcock station (station #3) is located on the branch line of the Rock Island. The Loyal station (station #4) is not served by a railroad. The location of each station and the railroad serving each station is shown in Figure 3.

Current Shipping Patterns

The railroad is currently the primary transportation mode used by the first three stations. The remaining wheat, including the Loyal station, is shipped by owned and hired trucks. A large portion of the wheat shipped by truck is moved by truck substitution or truck allowance. Truck substitution or truck allowance is used by the railroads when rail cars are not readily available. In this case, wheat is shipped by truck to Enid at the applicable rail rate with transit privileges. The railroad then reimburses the country grain elevator for all or part of the truck cost. The demonstration elevator owns only one truck, and that truck is used solely to haul wheat by truck substitution or truck allowance. Hired trucks are also used for this purpose. Hired truck hauls for other than truck substitution occurred primarily during the rail car shortage of 1972-73 and 1973-74. The destination of these hired truck hauls was Houston.

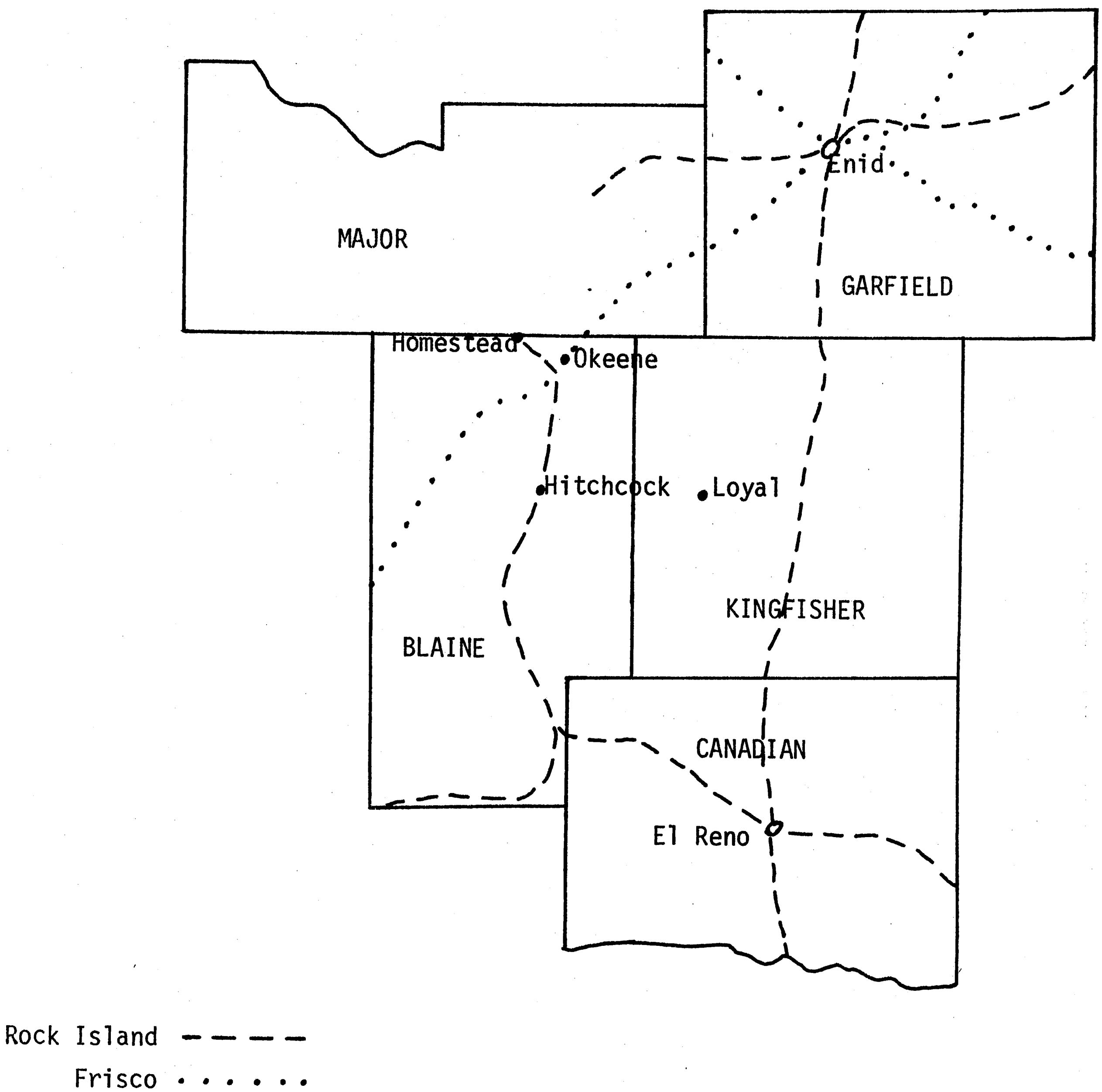


Figure 3. Location of Demonstration Elevator

Mixed Integer Programming Model

Model Assumptions

Several assumptions have been made in developing the mixed integer programming model for this study. These assumptions are:

1) that the country grain elevator manager wishes to minimize the total net present cost of shipping wheat;
2) that shipments are distributed evenly throughout each period (the program assumes the elevator manager will have some control on the amount of wheat shipped daily);
3) that costs remain constant throughout the year; costs do not vary between the harvest period and the rest of the year;
4) that a truck owned or leased in one period must be available for use in all other periods of the year (the program assumes that once the decision to own or lease a truck is made, that the owner will wish to utilize that truck to its capacity);
5) that the amount of wheat that must be shipped by the model during harvest and non-harvest periods may be approximated by an average of shipments from previous years; and
6) that the supply of hired trucks is unlimited to the country grain elevator.

The application of these assumptions will be seen later in this chapter while demonstrating the mixed integer programming model.

Model Variation

To measure the value of the railroad to the country grain elevator, the railroad will be gradually removed from the model. The change in total cost associated with the removal of rail is the value the country grain elevator places on rail service. This value is the maximum amount that the elevator would be willing to contribute toward retaining rail service.

The first model will simulate the actual grain transportation operation of the grain elevator. The model will not include any truck shipments to Catoosa, truck leasing or truck-rail activities. The second model will contain all of the potential transportation activities of the elevator, including truck shipments to Catoosa, truck leasing and truck-rail activities. The railroad will be removed from Homestead in the next model. Being a dead-end branch line on the Rock Island railroad, the possibility of such an event occurring is high. The fourth model will have no Rock Island rail service, leaving only the Okeene station on an active rail line. Finally, all rail activities, including truck-rail activities from the other stations to the Okeene station, will be removed from the model.

The above models will be made under two different circumstances. The five models discussed above will first be run with no restriction on the number of owned and leased trucks used. Then, to illustrate how outside influence may affect the optimal solution, the models will be run with a $100,000 capital constraint limiting the number of owned and leased trucks used by the elevator. The same could be accomplished by arbitrarily assigning a fixed number limit on trucks owned and leased. A description of each model can be found in Table VII. From this point on, models will be referred to by number.

TABLE VII

DESCRIPTION OF MODELS

Model #	Description
1	Resembles the current situation in that all activities in the model are currently considered alternative modes of transportation. Excludes truck activities to Catoosa, truck leasing and truck-rail activities. No limit on owned and leased trucks.
2	Includes truck activities to Catoosa, truck leasing and truck-rail activities. No limit on owned and leased trucks.
3	The branch line from Okeene to Homestead is removed from the model. No limit on owned and leased trucks.
4	The branch line from Okeene to Hitchcock is also removed. No limit on owned and leased trucks.
5	All rail activities of the country grain elevator are removed from the model, including truck-rail activities. No limit on owned and leased trucks.
6	Same as #1. $100,000 capital limit on owned and leased trucks.
7	Same as #2. $100,000 capital limit on owned and leased trucks.
8	Same as #3. $100,000 capital limit on owned and leased trucks.
9	Same as #4. $100,000 capital limit on owned and leased trucks.
10	Same as #5. $100,000 capital limit on owned and leased trucks.
11	Same as #2. But includes three week leased truck activity. Limited to three owned, annual leased and three week leased trucks each.
12	Same as #2. Limited to three owned and annual leased trucks each.

Linear Programming Format

The linear programming format has four basic parts: (1) objective function, (2) activity columns, (3) constraint and accounting rows, and (4) right hand sides. A discussion of each part and what it encompasses in this study will be found in the following sections.

Objective Function

The objective function of the linear programming model used in this study is to minimize net present cost. The objective function row contains the net present cost associated with each activity. The cost function formulas used in this study may be found in Table XVII Appendix B.

Activity Columns

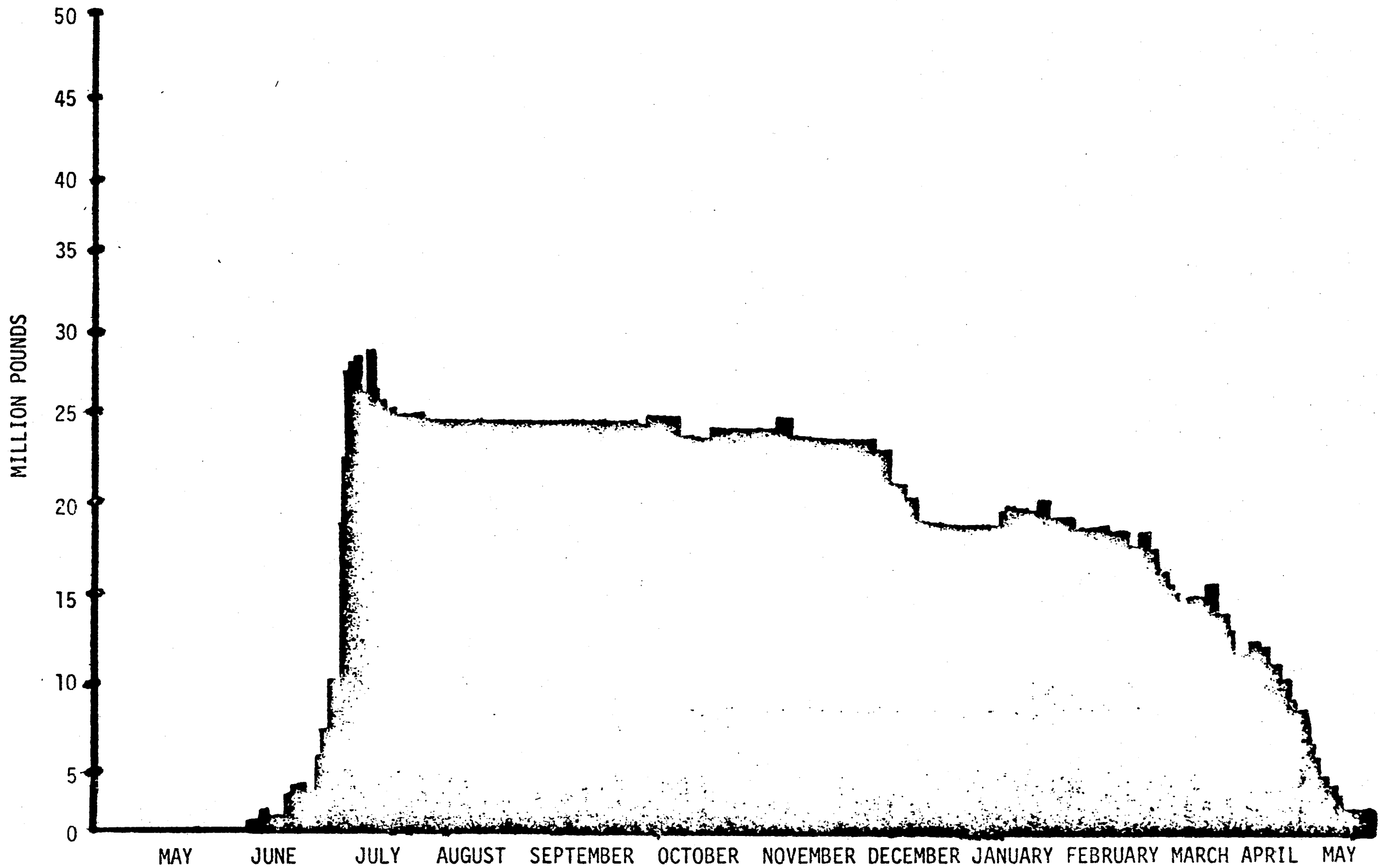
The number of activities associated with any one station is dependent on the time of the year and the modes of transportation available. During the harvest period, the basic activities associated with each station are: (1) rail to Houston, (2) rail to Enid, (3) owned truck to Catoosa, (4) leased truck to Catoosa, (5) hired truck to Catoosa, (6) owned truck to Enid, (7) leased truck to Enid, (8) hired truck to Enid, (9) owned truck to Okeene followed by rail to Enid, (10) leased truck to Okeene followed by rail to Enid and (11) hired truck to Okeene followed by rail to Enid. No wheat is trucked to Houston during harvest. Besides those activities previously mentioned, wheat may be shipped to Houston during the non-harvest period by (1) owned truck, (2) leased truck, and (3) hired truck. There is, or course, no direct rail service at any time from the Loyal station.

Constraint and Accounting Rows

Each station in this study will have two constraints on wheat shipments during the harvest period. The first harvest restriction requires the linear programming model to sell ten percent of the total harvest volume. This is the amount the demonstration elevator manager estimated would be sold by farmers during the harvest period of an average year. The second harvest restriction requires the model to ship all wheat in excess of the storage capacity of each station during the harvest period.

The only non-harvest period constraint on wheat shipments requires the model to ship the storage capacity of each station. Thus, the model ships all of the wheat in the elevator by the end of the year. The basis for a zero inventory at the end of the non-harvest period can be seen in Figure 4. The chart shown in Figure 4 would indicate that country grain elevators try to empty their storage bins before the hext harvest period begins. However, carryover inventory may be included in the model by subtracting it from capacity in the non-harvest period constraint. Together, these constraints tell the linear program how much, when, where and by what modes of transportation wheat should be shipped.

Accounting rows are used in a linear programming model to account for resources produced or utilized within the model. The rows may contain either positive or negative coefficients to determine an excess or deficiency of a resource, respectively. In this study, accounting rows are used to measure the number of bushels shipped, the number of truck hours used, and the number of hopper and box cars needed by the optimal solution.



*From Rail Wheat Transportation Efficiency Study - Problem Assessment, Marc A. Johnson, Gary M. Mennem, and Robert L. Oehrtman, Department of Agricultural Economics, Oklahoma State University.

Figure 4. Grain Inventories from One Country Grain Elevator in Western Oklahoma, 1974-75*

Right Hand Sides

Right hand sides are used in conjunction with row constraints to restrict the linear programming model. The formulas for the right hand sides of the constraint rows for each station are

Harvest Wheat Sold = 10% of Harvest Volume,

Harvest Wheat Shipment = Harvest Volume + Inventory Carryover - Storage Capacity

and,

Non-Harvest Wheat Shipment = Storage Capacity.

The coefficients for right hand sides in this study are an average of a five year period from 1971-72 to 1975-76.

Mixed Integer Programming Format

A mixed integer program is used in this study to determine the optimal number of owned and leased trucks in the optimal solutions of the model, subject to ownership constraints. Each type of truck selection (owned and leased) has one activity column in each period. The objective function of one of these columns is the total annual fixed cost of owning that type of truck. The objective function value of all other columns associated with that type of truck selection will be zero. The variable cost of operating owned or leased trucks is the objective function of each specific owned or leased truck activity. Constraint rows in the mixed integer programming format are designed to force the model to choose whole units or no units at all. The right hand side in the mixed integer program may limit trucks by number or by capital constraint. The format for the initial tableau used in the model for this study can be seen in Table XIX in Appendix C.

Model Demonstration

Previous sections of this chapter have discussed the details of the demonstration elevator and the outline of the mixed integer programming model used in this study. This chapter will now discuss the results of the models. Table VIII gives the net present cost of each model in this study. The number of owned and leased trucks selected by each model is shown in Table IX. As stated previously, two basic model sets were run. Each set of models will have five optimal solutions. The first solution of each model set will closely resemble the current shipping pattern of the country grain elevator. The first solution will have no truck leasing or Catoosa activities. The second solution of each model set will have all of the possible activities included. Rail service activities are then gradually removed in solutions three, four, and five. In addition, two models were run to determine the optimal length of truck leases. The optimal solutions of each set of models will now be discussed.

Models With Unlimited Owned and Leased Trucks

The first set of models (1-5) may select an unlimited number of owned and leased trucks. The total net present cost of Models 1 through 5 can be found in Table VIII. Models 2 and 3 have the lowest net present cost of the first model set. The two models differ in that Model 3

TABLE VIII

TOTAL NET PRESENT COST FOR ALL MODELS

Model #	Total Net Present Cost
1	$704,766.74
2	$689,275.80
3	$689,275.80
4	$690,651.03
5	$702,514.69
6	$744,934.66
7	$733,372.41
8	$733,697.40
9	$736,215.14
10	$759,840.38
11	$765,410.23
12	$765,410.56

TABLE IX

NUMBER OF OWNED AND LEASED TRUCKS SELECTED BY EACH MODEL

Model #	# of Owned Trucks	# of Leased Trucks
1	13	0
2	13	0
3	13	0
4	13	0
5	13	0
6	7	0
7	7	0
8	7	0
9	7	0
10	7	0
11	3	3*
12	3	3

*Program selected 3 annual leased trucks and 0 three-week leased trucks.

has no direct rail service at Homestead. The optimal solutions for Models 2 and 3, given in Table X, are the same. Since no Homestead rail activities were in the optimal solution of Model 2, the net present cost of Models 2 and 3 are also the same. Therefore, the country grain elevator with unlimited availability of owned and leased trucks would not be adversely affected by abandonment of the Homestead branch line. In addition, the difference in net present costs of Models 1, 2, and 3 indicates that the current shipping pattern is non-optimal due to the exclusion of the Port of Catoosa as a market.

The optimal solutions for all of the models with unlimited owned and leased trucks are given in Table X. Models 2 and 3, which have the lowest net present cost of the first model set, used owned truck activities extensively. Table IX shows that all models (1-5) in the first model set used 13 owned trucks, but no leased trucks. Rail service, when available, was used only during the harvest period. Thus, increased net present costs due to rail removal are incurred during the harvest period. As rail service is removed from the model set, owned and hired trucks come into the optimal solution.

Model With $100,000 Capital Limit on Owned and Leased Trucks

The first set of models assumed that the country grain elevator had unlimited use of owned and leased trucks. In reality, the elevator may be limited in the number of trucks it owns or leases. The elevator may be constrained by limited investment capital or perhaps by manager preference. To illustrate the effect of a limited number of owned and leased trucks, the second model set (6-10) is limited to a $100,000

TABLE X

OPTIMAL SOLUTIONS FOR MODELS WITH NO LIMIT ON OWNED AND LEASED TRUCKS

Model-Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
1-1	✓		21.67		Houston	Rail
1-1	✓		0.57		Enid	Rail
1-1	✓			366.63	Enid	Owned Truck
1-2	✓		12.02		Houston	Rail
1-2	✓			25.98	Enid	Owned Truck
1-3	✓		8.99		Houston	Rail
1-3	✓		48.19		Enid	Rail
1-4	✓			205.85	Enid	Owned Truck
1-1		✓		723.65	Houston	Owned Truck
1-1		✓		12.35	Houston	Hired Truck
1-2		✓		300.57	Houston	Owned Truck
1-3		✓		173.71	Houston	Owned Truck
1-4		✓		349.71	Houston	Owned Truck
2-1	✓			82.53	Catoosa	Owned Truck
2-1	✓		89.56		Enid	Rail
2-1	✓			27.64	Enid	Owned Truck
2-2	✓			27.48	Catoosa	Owned Truck
2-2	✓			25.98	Enid	Owned Truck
2-3	✓			34.23	Catoosa	Owned Truck
2-3	✓		48.19		Enid	Rail
2-4	✓			52.27	Catoosa	Owned Truck
2-4	✓			153.58	Enid	Owned Truck
2-1		✓		723.65	Houston	Owned Truck
2-1		✓		12.35	Houston	Hired Truck
2-2		✓		300.57	Houston	Owned Truck
2-3		✓		173.71	Houston	Owned Truck
2-4		✓		349.71	Houston	Owned Truck
3-1	✓			82.53	Catoosa	Owned Truck
3-1	✓		89.56		Enid	Rail

TABLE X (Continued)

Model-Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
3-1	✓			27.64	Enid	Owned Truck
3-2	✓			27.48	Catoosa	Owned Truck
3-2	✓			25.98	Enid	Owned Truck
3-3	✓			34.23	Catoosa	Owned Truck
3-3	✓		48.19		Enid	Rail
3-4	✓			52.27	Catoosa	Owned Truck
3-4	✓			153.58	Enid	Owned Truck
3-1		✓		723.65	Houston	Owned Truck
3-1		✓		12.35	Houston	Hired Truck
3-2		✓		300.57	Houston	Owned Truck
3-3		✓		173.71	Houston	Owned Truck
3-4		✓		349.71	Houston	Owned Truck
4-1	✓			82.53	Catoosa	Owned Truck
4-1	✓		96.82		Enid	Rail
4-2	✓			27.48	Catoosa	Owned Truck
4-2	✓			25.98	Okeene	Owned Truck-Rail
4-3	✓			34.23	Catoosa	Owned Truck
4-3	✓			183.56	Okeene	Owned Truck-Rail
4-4	✓			52.27	Catoosa	Owned Truck
4-4	✓			49.92	Enid	Owned Truck
4-4	✓			103.66	Okeene	Owned Truck-Rail
4-1		✓		723.65	Houston	Owned Truck
4-1		✓		12.35	Houston	Hired Truck
4-2		✓		300.57	Houston	Owned Truck
4-3		✓		173.71	Houston	Owned Truck
4-4		✓		349.71	Houston	Owned Truck
5-1	✓			82.53	Catoosa	Owned Truck
5-1	✓			368.79	Enid	Owned Truck
5-2	✓			27.48	Catoosa	Owned Truck
5-2	✓			25.98	Enid	Owned Truck

TABLE X (Continued)

Model-Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
5-3	✓			34.23	Catoosa	Owned Truck
5-3	✓			97.08	Enid	Owned Truck
5-3	✓			86.48	Enid	Hired Truck
5-4	✓			153.59	Enid	Owned Truck
5-1		✓		723.65	Houston	Owned Truck
5-1		✓		12.35	Houston	Hired Truck
5-2		✓		300.57	Houston	Owned Truck
5-3		✓		173.71	Houston	Owned Truck
5-4		✓		349.71	Houston	Owned Truck

capital investment in owned and leased trucks. The net present cost of Models 6 through 10 is shown in Table VIII. Model 7, which contains all available rail activities, has the lowest net present cost of the second model set. The net present cost of the models increase as rail service is removed.

Table XI gives the optimal solutions for each model in the second set of models. Model 7, with the lowest net present cost, has a combination of rail, owned truck and hired truck activities in the optimal solution. As rail activities are removed from Homestead and Hitchcock, they are replaced in the optimal solution by owned truck-rail activities. These owned truck-rail activities haul wheat by owned truck to Okeene, where it is loaded on rail cars and shipped to Enid. All wheat is hauled by owned and hired truck when all rail activities are taken out of the model. As with the first set of models, rail is used only during the harvest period. Any increased net present costs due to rail removal are incurred in the harvest period. Table IX shows that the optimal solutions of those models (6-10) constrained by a capital limit owned seven trucks and leased none.

The net present costs of models with unlimited owned and leased trucks (models 1-5) are less than the net present costs of those models constrained by a capital limit on owned and leased trucks (models 6-10). In this study, the respective models have selected 13 and seven owned trucks. Model 12, which is limited to three owned and leased trucks each, has a net present cost greater than any of the previously mentioned models. This leads to the conclusion that the net present cost of shipping wheat for a country grain elevator can be lowered by increasing the use of owned and leased trucks up to

TABLE XI

OPTIMAL SOLUTIONS FOR MODELS WITH $100,000 CAPITAL LIMIT ON OWNED AND LEASED TRUCKS

Model-Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
6-1	✓		21.67		Houston	Rail
6-1	✓		63.79		Enid	Rail
6-1	✓			125.79	Enid	Owned Truck
6-2	✓		12.02		Houston	Rail
6-2	✓		11.37		Enid	Rail
6-3	✓		8.99		Houston	Rail
6-3	✓		48.19		Enid	Rail
6-4	✓			205.85	Enid	Owned Truck
6-1		✓		483.64	Houston	Owned Truck
6-1		✓		252.36	Houston	Hired Truck
6-2		✓		300.57	Houston	Hired Truck
6-3		✓		173.71	Houston	Hired Truck
6-4		✓		349.71	Houston	Owned Truck
7-1	✓			82.53	Catoosa	Owned Truck
7-1	✓		96.82		Enid	Rail
7-2	✓			27.48	Catoosa	Owned Truck
7-2	✓		11.37		Enid	Rail
7-3	✓			34.23	Catoosa	Owned Truck
7-3	✓		48.19		Enid	Rail
7-4	✓			52.27	Catoosa	Owned Truck
7-4	✓			153.58	Okeene	Owned Truck-Rail
7-1		✓		532.78	Houston	Owned Truck
7-1		✓		203.22	Houston	Hired Truck
7-2		✓		300.57	Houston	Owned Truck
7-3		✓		173.71	Houston	Hired Truck
7-4		✓		349.71	Houston	Hired Truck
8-1	✓			82.53	Catoosa	Owned Truck
8-1	✓		96.82		Enid	Rail

TABLE XI (Continued)

Model Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
8-2	✓			27.48	Catoosa	Owned Truck
8-2	✓			25.98	Okeene	Owned Truck-Rail
8-3	✓			34.23	Catoosa	Owned Truck
8-3	✓		48.19		Enid	Rail
8-4	✓			52.27	Catoosa	Owned Truck
8-4	✓			153.58	Okeene	Owned Truck-Rail
8-1		✓		532.78	Houston	Owned Truck
8-1		✓		203.22	Houston	Hired Truck
8-2		✓		300.57	Houston	Owned Truck
8-3		✓		173.71	Houston	Hired Truck
8-4		✓		349.71	Houston	Hired Truck
9-1	✓		0.71		Houston	Rail
9-1	✓			79.82	Catoosa	Owned Truck
9-1	✓		96.82		Enid	Rail
9-2	✓			27.48	Catoosa	Owned Truck
9-2	✓			25.98	Okeene	Owned Truck-Rail
9-3	✓			34.23	Catoosa	Owned Truck
9-3	✓			183.56	Okeene	Owned Truck-Rail
9-4	✓			52.27	Catoosa	Owned Truck
9-4	✓			153.58	Okeene	Owned Truck-Rail
9-1		✓		9.35	Houston	Owned Truck
9-1		✓		726.65	Houston	Hired Truck
9-2		✓		300.57	Houston	Owned Truck
9-3		✓		173.71	Houston	Owned Truck
9-4		✓		349.71	Houston	Owned Truck
10-1	✓			82.53	Catoosa	Owned Truck
10-1	✓			28.91	Enid	Owned Truck
10-1	✓			339.88	Enid	Hired Truck
10-2	✓			27.48	Catoosa	Owned Truck
10-2	✓			25.98	Enid	Hired Truck

TABLE XI (Continued)

Model Station	# Harvest	Non-Harvest	Carloads	Truckloads	Destination	Mode
10-3	✓			34.23	Catoosa	Owned Truck
10-3	✓			183.56	Enid	Hired Truck
10-4	✓			52.27	Catoosa	Owned Truck
10-4	✓			153.58	Enid	Owned Truck
10-1		✓		309.92	Houston	Owned Truck
10-1		✓		426.08	Houston	Hired Truck
10-2		✓		300.57	Houston	Hired Truck
10-3		✓		173.71	Houston	Owned Truck
10-4		✓		349.71	Houston	Owned Truck

a certain optimum level. The optimum level can be determined by a mixed integer programming model with unlimited truck ownership.

<u>Optimal Length of Truck Lease</u>

One problem facing the country grain elevator manager is the length of truck leases. To determine the optimal length of truck leases, two additional models were run. Model 11, which includes all potential transportation activities, has two different truck leasing activities for each time period. The first truck leasing activity, which is used in every model that has a truck leasing activity, is based on a one year lease. The second truck leasing activity is based on a three week lease. Owned, annual leased and three-week leased trucks were limited to three trucks each.

The net present cost and number of trucks used by Model 11 may be found in Table VIII and Tabls IX, respectively. Model 12 has the same activities and restrictions as Model 11, except the three-week leased truck activity is not included. A comparison of the figures given in Table VIII and Table IX indicate that the shorter lease period (model 11) does not replace the annual leased truck activity in the optimal solution. The number and kind of trucks used remains unchanged, and net present cost is unaffected.

<u>Opportunity Cost of Rail Service</u>

The opportunity cost of rail service is the maximum amount of money the country grain elevator should be willing to contribute toward retaining rail service on a line segment. Table XII presents the opportunity cost of rail service of each line segment for models

TABLE XII

ANNUAL OPPORTUNITY COSTS OF RAIL SERVICE AND CAPITAL FOR THE DEMONSTRATION ELEVATOR

Column Rail Segment	A Opportunity Cost Unlimited Trucks*	B Opportunity Cost Capital Constraint*	C Opportunity Cost of Capital**	D Average Shadow Price on Capital***
Homestead	$ -0-	$ 324.99	$ 44,421.60	58%
Hitchcock	1,375.23	2,517.74	45,564.11	59%
Okeene	11,863.66	23,625.24	57,325.69	74%
Total	$13,238.89	$26,467.97	$147,311.40	191%

*Opportunity cost of rail service to a station = Net present cost of the model without rail service − Net present cost of the model with rail service

**Opportunity cost of capital = Net present cost of model with capital investment − Net present cost of model with unlimited trucks

***Average opportunity cost per dollar of additional capital investment $= \dfrac{\text{Opportunity Cost of Capital}}{\$177{,}179.73^{\neq} - 100{,}000^{\#}}$

≠Capital investment in models with unlimited owned and leased trucks.

#Capital constraint in models with limited owned and leased trucks.

with unlimited and constrained truck use. The opportunity cost of rail service for a rail segment is determined by subtracting the net present cost of a model with rail service to a specific station from the net present cost of a model without rail service to the same specific station. The net present costs for all models is given in Table VIII. To illustrate the opportunity cost of rail service, the opportunity cost of rail service to Homestead is

$689,275.80(model 3) - $689,275.80(model 2) = $0.

The opportunity cost of capital and the average shadow price on capital for each line segment is also shown in Table XII. A discussion of the components of Table XII follows.

Opportunity Cost of Rail Service For Models With Unlimited Owned and Leased Trucks

The opportunity cost of rail service for models with unlimited owned and leased trucks is given in column A of Table XII. With unlimited owned and leased truck use, the Homestead branch line has no value to the country grain elevator. As shown in the example in the previous section, the opportunity cost of rail at Homestead is zero when owned and leased trucks are unlimited. The country grain elevator does not need the rail service provided at Homestead to minimize net present cost. The opportunity cost of rail service at Hitchcock is the difference between the net present costs of Model 3 and Model 4 from Table VIII. Thus, the Hitchcock line segment is valued at $1,357 annually by the elevator. The value of Okeene rail service is found by subtracting the net present costs of Model 4 and Model 5, i.e., $11,864 annually.

The sum of column A in Table XII, $13,239, is the total value the country grain elevator places on rail service. Since the line segments serving Hitchcock and Okeene also serve numerous other businesses, the country grain elevator at Okeene may be willing to annually contribute up to the amounts mentioned above to a shippers' association attempting to retain rail service.

Opportunity Cost of Rail Service for Models With $100,000 Capital Limit on Owned and Leased Trucks

The opportunity cost of rail service for models with a capital limit on owned and leased trucks can be found in column B of Table XII. The value of each rail segment to the country grain elevator increased when the number of owned and leased trucks was constrained. The interpretation of the opportunity cost of rail service remains the same as with unlimited owned and leased trucks. The opportunity cost of rail service at Homestead is found by subtracting the net present costs of Model 7 and Model 8 from Table VIII, and is $325 annually. Thus, Homestead rail service is still of little value to the demonstration elevator. The value of Hitchcock rail service is the difference in net present costs of Model 8 and Model 9, and is $2,518 annually. Likewise, the value of Okeene rail service when owned and leased trucks are constrained by a capital limit is $23,625. This is found by subtracting the net present costs of Model 9 from Model 10.

The sum of volumn B in Table XII, $26,468, is the total value the country grain elevator places on rail service. The country grain elevator may be willing to annually contribute up to the opportunity costs of the Hitchcock and Okeene line segments to a shippers' association attempting to retain rail service.

Opportunity Cost of Capital

The opportunity cost of capital for owned and leased trucks is given in column C of Table XII. The opportunity cost of capital is the maximum return available to the country grain elevator which could be obtained by increasing capital investment from $100,000 in owned and leased trucks to $177,180 to achieve the optimum solution.

The opportunity cost of capital for a specific rail segment is found by subtracting net present cost of a model with unlimited owned and leased trucks from the net present cost of a model with a capital constraint on owned and leased trucks. Thus, the opportunity cost of capital for Homestead is the difference in net present costs of Model 3 and Model 8, and is $44,422 annually. The opportunity cost of capital for Hitchcock is $45,564 annually and is found by subtracting the net present costs of Model 4 and Model 9. Finally, the opportunity cost of capital for Okeene is the difference in the net present costs of Model 5 and Model 10 and is $57,326 annually. The sum of column C in Table XII, $147,311, is the total return available to the country grain elevator from increasing capital investment in owned and leased trucks to the optimum level.

Average Shadow Price on Capital

The average opportunity cost per dollar of additional capital investment is shown in column D of Table XII. The average shadow price on capital for each line segment is an estimate of the average rate of return on the additional capital required to increase the number of owned trucks used in the model set with a capital constraint to the level of models without a capital constraint. The rate of return on additional capital investment in trucks is very high for each rail segment, being well over 50%. The sum of column D, shows an average rate of return for the entire elevator of nearly 200%. This indicates that the return on a dollar of capital investment in owned or leased trucks is nearly doubled. Under those circumstances, the demonstration elevator would be expected to increase its capital investment in owned trucks.

CHAPTER V

SUMMARY AND CONCLUSIONS

Country grain elevators in Oklahoma have, in the past, relied on rail transportation to move a large portion of the wheat crop to domestic and export markets. However, some railroad trackage located in the Oklahoma wheat belt is susceptible to abandonment because of track deterioration. Two major railroads serving the state are in serious financial condition which may also create abandonment problems. Country grain elevator owners and managers facing abandonment must look toward other modes of transportation. Basically, country grain elevators may:

1) revert to some type of truck operation;
2) make rail shipping or receiving, or other operating arrangements with an elevator located on another line not likely to ba abandoned;
3) pay higher rail rates or a lump sum subsidy through a shippers' association in order to retain rail service; or
4) contribute through a shippers' association towards the purchase of part or all of the line to be abandoned, for operation as a short line railroad.

Given the need for country grain elevator's to look for alternative modes of transportation, the purpose of the research presented in the study was to design a systematic approach to guide the elevator owner or manager in the optimal selection of available transportation alternatives. The study had three specific objectives. The first objective was to develop an operational procedure to guide the country grain elevator manager in selection of optimal long run adjustments in transportation. The second objective was to develop a procedure to measure the magnitude of contribution a country grain elevator could afford to pay toward retaining rail service, purchasing a short line or borrowing federal funds. Finally, the study intended to demonstrate the techniques developed by determining the optimal long run adjustment in transportation for a country grain elevator currently operating in northwest Oklahoma.

The decision-making tool developed in this study was implemented by use of a mixed integer programming model. Procedures were developed to construct the coefficients that go into the mixed integer programming model. The magnitude of contribution a country grain elevator could make toward retaining rail service or other ventures was determined by finding the amount of increase in net present cost between a model containing rail activities to a particular station and a model without the same rail activities. The model was demonstrated by selecting a country grain elevator located in Okeene, Oklahoma. Additional stations associated with the elevator are located at Homestead, Hitchcock and Loyal. Data collected from these stations were used to determine the proper activities, restrictions and coefficients for the model.

Conclusions

The intent of this study was to design a systematic approach to guide the country grain elevator owner and manager in the optimal selection of available transportation alternatives. This study found that a mixed integer programming model could be suitably operationalized to perform this task. The mixed integer programming model developed in this study was capable of selecting optimal long run adjustments in the transportation modes employed by a country grain elevator located on a rail line subject to abandonment. The mixed integer programming model was also found useful in improving current transportation mode selection.

A procedure was also developed to measure the magnitude of contributions a country grain elevator may be willing to make toward retaining rail service, purchasing a short line or borrowing federal funds. That procedure employed the results of the mixed integer programming model to determine the opportunity cost or value of a rail line segment to the country grain elevator. The cost of investment capital to own or lease trucks and an average rate of return on additional capital investment were also components of the procedure developed in this study.

The results of the model demonstration in Chapter IV indicated that country grain elevators in northwest Oklahoma should consider shipping more wheat by truck. The model demonstration also indicated that some wheat should perhaps be shipped to the terminal elevator at the Port of Catoosa. This differs significantly from present practices of country grain elevators.

The result of the models run indicated that the net present cost of the country grain elevator would increase as the number of owned and leased trucks in the model decreased. The net present cost of transportation increased as rail activities were removed from the model. Rail activities appeared in the optimal solution only during the harvest period. When the number of owned and leased trucks was limited, rail was replaced in the optimal solution with owned truck-rail activities. With unlimited owned trucks available, rail was replaced by owned and hired trucks. All wheat was shipped to Houston by owned and hired trucks during the non-harvest period. Finally, when all rail activities are removed from the model, all wheat is shipped by owned and hired truck in both periods.

Using the results of the models run, the opportunity cost of rail service was found to be minimal for the Homestead station. The value of the Hitchcock rail segment was greater than at Homestead but not extremely large. However, the opportunity cost of rail services to Okeene and the total opprotunity cost of all three line setments was great enough to encourage increased capital investment in owned trucks at the discount rate employed by this study. The average rate of return on additional capital investment in owned and leased trucks is well over 50% for each rail segment.

Limitations of the Study

The results of the demonstration model may have been affected by limitations imposed on the model. Among the limitations imposed on the model was dividing the year into only two shipping periods: (1) harvest and (2) non-harvest. A greater number of periods reflecting significant fluctuations in shipping patterns may better reflect actual mode requirements. The model does not include activities or restrictions on incoming shipments of products (such as fertilizer, feed, and other farm supplies) that may be handled by many country grain elevators. The availability of hired trucks and rail cars was assumed to be unlimited. In reality, the availability of hired trucks and rail cars may be limited during some shipping periods. Siding capacity and service frequency may also limit railroad movements during harvest. In addition, hired truck rates were assumed constant throughout the year. This assumption would not necessarily hold in situations where hired trucks were limited in number. Finally, owned and leased truck budgets for this study were based on the cost of operation of a single truck owned by the demonstration elevator. More and better data are needed to confirm the accuracy of the budgets used.

Recommendations for Further Study

Additional research is needed concerning application of the model to all of the business operations of a country grain elevator. To properly determine the best alternative modes of transportation for an elevator, the manager of that elevator must also consider the transportation needs of incoming shipments such as fertilizer, feed or other farm supplies. More research also needs to be done on model needs for country grain elevators handling more than one crop.

Research on truck ownership costs is limited. Information on the relationship of truck use and increasing maintenance and repair costs is not readily available. Additional study is needed on the availability of hired trucks and rates charged. Research is also needed on the competitive advantage of trucks versus rail.

Hopefully, this study will serve as a foundation for future research in selecting alternative modes of transportation.

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APPENDIX A

ORGANIZATION INFORMATION

1. Name of Elevator ______________________

   Address ______________________

   Phone ______________________

   Manager ______________________

2. Names of Branch Stations and Their Addresses

   ____

   ____

   ____

3. Do you have binding relationships, either contractual or informal, with specific inland terminal elevators or other buyers?

   Yes _____ No _____

   If yes, please explain. ______________________

   ____

STORAGE CAPACITY

4. What is the total storage capacity of the elevator?

   licensed _________bu.

   upright _________bu.

   flat _________bu.

5. At the time of wheat harvest, what part of storage capacity is not available for wheat storage? _________bu.

   Please explain. ______________________

   ____

6. What is the storage capacity of each station?

Station	Storage Capacity
______	______________
______	______________
______	______________
______	______________

RAIL INFORMATION

7. What railroad(s) serve the elevator? ________________________

____

8. Which days each week do you have train service from each railroad?

Railroad	________	________
Normal times	________	________
Harvest periods	________	________

9. How many rail cars can be handled and loaded on your rail siding without switching cars? ________________________

____

10. On the average, how many hopper cars and boxcars can you load during one shift of eight hours?

Hopper cars ________

Boxcars ________

11. Do you lease rail cars?

Yes _____ No _____

If yes, please explain. ________________________

____

12. Are rail cars spotted at the elevator for loading?

Yes _____ No _____

If not, how are they spotted? ____________________

How long does it take? ____________________

13. Is any of the track serving each station under any kind of weight restriction? ____________________

____

14. How long does it take the railroad to fill your order for grain cars?

Longest Time __________ days Month/Year __________

Shortest Time __________ days Month/Year __________

Typical harvest time __________ days

Typical non-harvest time __________ days

15. During harvest periods, do you typically receive the number and type of rail cars ordered?

Yes _____ No _____

If no, please explain. ____________________

____

16. Do rail cars come to you in a condition ready for loading?

Hopper cars Yes _____ No _____

Boxcars Yes _____ No _____

If no, how many man-hours does it take to put them in loading condition? ____________________

17. What rate do you currently pay for shipping wheat by rail?

____

18. Do the railroads serving your elevator offer the truck substitution alternatives to rail service?

Yes _____ No _____

If yes, do you take advantage of this service?

Yes _____ No _____

If no, why not? ____

____

If yes, how many bushels of wheat were shipped by truck substitution in the following years?

	1971-72	1972-73	1973-74	1974-75	1975-76
Wheat (bu.)	_____	_____	_____	_____	_____
Destination	_____	_____	_____	_____	_____
Station	_____	_____	_____	_____	_____

19. Have you experienced wheat losses in transit by railroad?

Yes _____ No _____

If yes, in what quantities? (dollar values)

1971-72	1972-73	1973-74	1974-75	1975-76
_____	_____	_____	_____	_____

How long does it take before your loss claim is paid?

____

Have you had difficulties having claims honored?

Yes _____ No _____

If yes, please explain. ______________________________________

20. In the past five years how much grain was shipped by truck which would have been shipped by rail had service been available?

	1971-72	1972-73	1973-74	1974-75	1975-76
Bushels	_____	_____	_____	_____	_____
Destination	_____	_____	_____	_____	_____
Station	_____	_____	_____	_____	_____

TRUCK INFORMATION

21. Do you own grain trucks?

Yes _____ No _____

If yes, please answer the following:

What types? ____________________

What tag capacities? ____________________

What number of axles? ____________________

What number of miles used per quarter? ____________________

What number of units? ____________________

What length of ownership? ____________________

What type of depreciation? ____________________

22. Truck ownership costs:

Fixed costs (annual)

Tractor investment ____________________

Trailer investment ____________________

Licenses and permits ____________________

Taxes

- Highway use ____________________
- Social Security ____________________
- Unemployment ____________________

Insurance

- Workers Compensation ____________________
- Health and Medical ____________________
- Revenue Equipment ____________________

<u>Variable</u> <u>Costs</u> (annual)

Fuel ______________

Oil ______________

Filters and gaskets ______________

Grease ______________

Batteries ______________

Tires ______________

Maintenance and repair ______________

Driver compensation ______________

23. Do you lease grain trucks?

Yes _____ No _____

If yes, please answer the following:

What types? ______________________________

What tag capacities? ______________________________

What number of axles? ______________________________

Current lease prices? ______________________________

Current lease terms? ______________________________
(period, maintenance, etc.)

What number of miles used per quarter? ______________

What number of units? ______________________________

24. How many bushels of wheat are shipped with leased trucks?

	1971-72	1972-73	1973-74	1974-75	1975-76
# of trips	______	______	______	______	______
Destination	______	______	______	______	______
Station	______	______	______	______	______

25. Do you use for-hire trucks?

Yes _____ No _____

If yes, please answer the following:

What types? ____

What tag capacities? ________________________________

What number of axles? ______________________________

Type of hire? (contract, single load) ________________

____

26. How long does it take to receive for-hire trucks once you request them?

Harvest time __________

Normal time __________

27. How many bushels of wheat are shipped with for-hire trucks?

	1971-72	1972-73	1973-74	1974-75	1975-76
# of trips	______	______	______	______	______
Destination	______	______	______	______	______
Station	______	______	______	______	______

28. During harvest, can you load semi-trailers without interfering with the delivery of grain by producers?

Yes _____ No _____

How long does it take to load a semi-trailer truck? __________

____

29. Have you experienced losses in transit by truck?

Yes _____ No _____

If yes, in what quantities? (dollar values)

1971-72	1972-73	1973-74	1974-75	1975-76
______	______	______	______	______

How long does it take before your loss claim is paid? ____________

____

Have you had difficulties having claims honored? ____________

30. What rates do you pay for-hire trucks? ____________________

____

SHIPPING INFORMATION

31. How many bushels of wheat were shipped by the following modes of transportation from each station?

		1971-72	1972-73	1973-74	1974-75	1975-76
______ (Station)	Volume (bu.)	______	______	______	______	______
	Rail	______	______	______	______	______
	Truck	______	______	______	______	______
	Inventory	______	______	______	______	______

32. What percent of the total wheat volume for each station is sold during the harvest period? ____________________

____

33. What is the typical length of the harvest period for your elevator?

____

34. What are the operating hours of the elevator?

Harvest time ____________

Normal time ____________

APPENDIX B

TABLE XIII

COST FORMULAS USED IN THE MODEL DEMONSTRATION

<u>Rail</u>

To Houston = Rail rate per bu. (37¢) x 3383 bu.*

To Enid = Same

<u>Owned and Leased Trucks</u>

To Houston = Per hour cost (from budgets) x trip time (20 hours)

To Catoosa = [Per hour cost (from budgets) x trip time] + [Catoosa bid spread of 26¢ bu. x 875 bu.]

To Enid = [Per hour cost (from budgets) x trip time] + [Enid bid spread of 36¢ bu. x 875 bu.]

<u>Hired Truck</u>

To Houston = Watonga rate per bu. (36¢) x 875 bu.

To Catoosa = [Watonga rate per bu. (16¢) + Catoosa bid spread (26¢)]x 875 bu.

To Enid = [Hired truck rate per bu. (6.3¢) + Enid bid spread (36¢)] x 875 bu.

<u>Owned and Leased Truck-Rail</u>

= [Per hour cost (from budgets) x trip time to Okeene] + [rail rate per bu. (37¢) x 875 bu.]

<u>Hired Truck-Rail</u>

[Hired truck rate per bu. (6.3¢) + rail rate per bu. (37¢)] x 875 bu.

*2,000 bu. if from Homestead.

TABLE XIV

ACTIVITY TIME USED IN THE MODEL DEMONSTRATION

			Harvest Period		
Trip	Milage	Load Time	Driving Time (Both Ways)	Unloading Time	Total Time
Okeene to Enid	40	:45	2:30	1:00	4:15 (4.25)*
Okeene to Houston	--	---	20:00	----	20:00 (20)
Okeene to Catoosa	155	:45	6:55	:30	8:10 (8.17)
Homestead to Okeene	6	:45	:25	:40	1:50 (1.83)
Homestead to Enid	40	:45	2:30	1:00	4:15 (4.25)
Homestead to Houston	--	---	20:00	----	20:00 (20)
Homestead to Catoosa	161	:45	7:10	:30	8:25 (8.42)
Hitchcock to Okeene	8	:45	:30	:40	1:55 (1.92)
Hitchcock to Enid	48	:45	3:00	1:00	4:45 (4.75)
Hitchcock to Houston	--	---	20:00	----	20:00 (20)
Hitchcock to Catoosa	163	:45	7:15	:30	8:30 (8.5)
Loyal to Okeene	18	:20	1:10	:40	2:10 (2.17)
Loyal to Enid	40	:20	2:30	1:00	3:50 (3.83)
Loyal to Houston	--	---	20:00	----	20:00 (20)
Loyal to Catoosa	173	:20	7:40	:30	8:30 (8.5)

*Time in Fractions of an Hour.

Explanation of Time Allotment - Harvest Period

Load Time: Load time at Okeene, Homestead and Hitchcock is :20 longer than during the non-harvest period. The breakdown is :15 to load and :30 of delay time. Loyal load time is increased :05 over the non-harvest period. The breakdown is :05 to load and :15 of delay time. The Loyal loading time is shorter because the station loads only trucks and loading is not hampered by grain being delivered to Loyal.

Driving Time: No change from non-harvest period.

Unloading Time: Unloading time is doubled during the harvest period for all stations except Catoosa. The Catoosa terminal claims no delays due to harvest.

TABLE XIV (Continued)

Trip	Milage	Load Time	Non-Harvest Period Driving Time (Both Ways)	Unloading Time	Total Time
Okeene to Enid	40	:25	2:30	:30	3:25 (3.42)
Okeene to Houston	--	---	20:00	---	20:00 (20)
Okeene to Catoosa	155	:25	6:55	:30	7:50 (7.83)
Homestead to Okeene	6	:25	:25	:20	1:10 (1.17)
Homestead to Enid	40	:25	2:30	:30	3:25 (3.42)
Homestead to Houston	--	---	20:00	---	20:00 (20)
Homestead to Catoosa	161	:25	7:10	:30	8:05 (8.08)
Hitchcock to Okeene	8	:25	:30	:20	1:15 (1.25)
Hitchcock to Enid	48	:25	3:00	:30	3:55 (3.92)
Hitchcock to Houston	--	---	20:00	---	20:00 (20)
Hitchcock to Catoosa	163	:25	7:15	:30	8:10 (8.17)
Loyal to Okeene	18	:15	1:10	:20	1:45 (1.75)
Loyal to Enid	40	:15	2:30	:30	3:15 (3.25)
Loyal to Houston	--	---	20:00	---	20:00 (20)
Loyal to Catoosa	173	:15	7:40	:30	8:25 (8.42)

Explanation of Time Allotment - Non-Harvest Period

Load Time: Load time at Okeene, Homestead, and Hitchcock is based on :15 to load and :10 to weigh and delay time. Load time at Loyal is based on :05 to load and :10 to weigh and delay time.

Driving Time: Driving time to Enid and Okeene is based on the milage from Okeene to Enid (40 miles) and the driving time estimated by the demonstration elevator's manager. The formula is:

Milage ÷ 40 x 2.5 = Driving Time

Driving time to Catoosa was based on the assumption of an average speed of 45 m.p.h. The formula is:

Milage ÷ 45 x 2 = Driving Time.

Unloading Time: Enid time is based on an estimate of the demonstration elevators' manager. Okeene time is an estimate, figuring that it would take :05 or less to dump a trailer and :15 delay time. Catoosa time is based on the claim that the Catoosa terminal unloads a trailer every :16 minutes. For this study, the time was increased to :30 to allow for delays. The Houston time is based on the demonstration elevators' manager estimate of two days for a round trip.

TABLE XV

ANNUAL OWNED TRUCK BUDGET USED IN THE MODEL DEMONSTRATION

FIXED COSTS	
8% Discounted Tractor payments ($36,450-$12,000 (.73503)/3.312)	$ 8,342.28
8% Discounted Trailer payments ($11,000-$1,800 (.46319)/6.710)	1,515.09
License and Permit (From demonstration elevator)	712.15
Taxes	
Highway use (From demonstration elevator)	430.00
Social Security (5.85% x $12,531.37)	733.09
Unemployment (1.2% x $4,200)	50.40
Insurance	
Workman's Compensation (From demonstration elevator)	380.00
Health and Medical (From demonstration elevator)	310.20
Revenue Equipment (From demonstration elevator)	1,156.00
Total Annual Fixed Costs	$13,629.21
VARIABLE COSTS (Based on 32,504 miles per year)	
Fuel (44¢/gal., 4 mi./gal.)	3,575.44
Oil (From demonstration elevator)	174.94
Filters, Gaskets, Grease, and Batteries (From demonstration elevator)	147.00
Tires (From demonstration elevator)	447.55
Maintenance and Repair (From demonstration elevator)	1,690.71
Driver Compensation (From demonstration elevator)	12,531.37
Total Annual Variable Cost	$18,567.01

Variable Cost per Hour = $18,567.01 ÷ 2716.5 = $6.835

TABLE XVI

HOURS OF AVAILABLE TRUCK USE IN THE MODEL DEMONSTRATION

Harvest Period

16 hours per day x 21 days = 336 hours

(Based on operating hours of 8 a.m. to MIDNIGHT)

Non-Harvest Period

6 - holidays (New Years, Memorial Day, Independence Day, Labor Day, Thanksgiving, Christmas)

49 - Sundays (excluding Sundays during harvest)

24.5 - One half day Saturdays

21 - days of harvest

100.5 - days of non-operation

Based on the operating hours in effect during the rest of the year (8 a.m. - 5 p.m., 1/2 day Saturday), a 9 hour average day will be used. Thus, total number of hours during the rest of the year is

(365 days - 100.5 days) x 9 hours/day = 2380.5 hours.

Total Available Truck Time

Total number of hours = Harvest Period + Non-Harvest Period

2716.5 hours = 336 hours + 2380.5 hours

TABLE XVII

ANNUAL LEASED TRUCK BUDGET USED IN THE MODEL DEMONSTRATION

FIXED COSTS	
8% Discounted Trailer Payments ($11,000 - $1,800 (.46319)/6.710)	$ 1,515.09
Tractor Rental ($315 x 50/wks.)	15,750.00
Taxes	
Social Security (5.85% x $12,531.37)	733.09
Unemployment (1.2% x $4,200)	50.40
Insurance	
Workmans' Compensation (From demonstration elevator)	380.00
Health and Medical (From demonstration elevator)	310.20
Revenue Equipment (From demonstration elevator)	310.00
Total Annual Fixed Costs	$19,048.78
VARIABLE COSTS	
Tractor Rental (16¢/mi. x 32,504 mi.)	$ 5,200.64
Fuel (44¢/bal. ÷ 4 mi./gal. x 32,504 mi.)	3,575.44
Driver Compensation (From demonstration elevator)	12,531.37
Total Annual Variable Costs	$21,307.45
Variable Cost per Hour = $21,307.45 ÷ 2716.5 = $7.844	

TABLE XVIII

HIRED TRUCK BUDGETS USED IN THE MODEL DEMONSTRATION

FROM LOCAL TO HOUSTON = 36¢/bu. x 875 bu./load = $315/load

FROM LOCAL TO ENID = (6.3¢/bu. + 36¢/bu.) x 875 bu./load = $370.13/load

FROM LOCAL TO CATOOSA = (16¢/bu. + 26¢/bu.) x 875 bu./load

= $367.50/load

HIRED TRUCK-RAIL = (6.3¢/bu. + 37¢/bu.) x 875 bu./load = $378.88/load

---

APPENDIX C

TABLE XIX

EXAMPLE OF THE MIXED INTEGER PROGRAM USED IN THE MODEL
WITH UNLIMITED OWNED AND LEASED TRUCKS

	Harvest Period				Non-Harvest Period				
OBJF	Okeene-Catoosa Owned Truck 283.34	Okeene-Catoosa Leased Truck 291.59	Owned Truck Fixed Cost 13,629.21	Leased Truck Fixed Cost 19,048.78	Okeene-Catoosa Owned Truck 281.02	Okeene-Catoosa Leased Truck 288.92	Owned Truck 0-1 -0-	Leased Truck 0-1 -0-	Right Hand Side
Owned Truck 0-1 (Harvest Period)	0		1.0						
Owned Truck Lower Limit (Harvest Period)	-8.17		189.0						≤ 0
Owned Truck Upper Limit (Harvest Period)	8.17		-336.0						≤ 0
Leased Truck 0-1 (Harvest Period)		0		1.0					
Leased Truck Lower Limit (Harvest Period)		-8.17		189.0					≤ 0
Leased Truck Upper Limit (Harvest Period)		8.17		-336.0					≤ 0
Owned Truck 0-1 (Non-Harvest Period)			-1.0		0		1.0		≤ 0
Owned Truck Lower Limit (Non-Harvest Period)					-7.83		1340.0		≤ 0
Owned Truck Upper Limit (Non-Harvest Period)					7.83		-2381.0		≤0
Leased Truck 0-1 (Non-Harvest Period)						0		1.0	≤ 0
Leased Truck Lower Limit (Non-Harvest Period)						-7.83		1340.0	≤ 0
Leased Truck Upper Limit (Non-Harvest Period)						7.83		-2381.0	≤ 0

TABLE XX

DETERMINATION OF THE MINIMUM NUMBER OF HOURS OF AVAILABLE TRUCK TIME USED IN THE MODEL OWNED TRUCK VERSUS LEASED TRUCK IN THE NON-HARVEST PERIOD

FC + VC(Q) = P(Q)

Enid

$13,629.21 + $6.835 Q = $108.08

Q = 125.91 ÷ 2716.5 hours = 4.64%

Catoosa

$13,629.21 + $6.835 Q = $47.04

Q = 338.99 ÷ 2716.5 hours = 12.48%

Houston

$13,629.21 + $6.835 Q = $15.75 Q

Q = 1528.80 ÷ 2716.5 hours = 56.28%

@ 56.28%

	Harvest Period	Non-Harvest Period
Minimum Hours	189	1340

Where:

FC = Fixed cost of owned truck;
VC = Variable cost of owned truck;
Q = Breakeven point in hours between owned and leased trucks; and

P_{Enid} = $370.13 x (1 ÷ 3.42 hrs.)
= $108.08

$P_{Catoosa}$ = $367.50 x (1 ÷ 7.83 hrs.)
= $47.04

$P_{Houston}$ = $315 x (1 ÷ 20 hrs.)
= $15.75

ν

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