Alternative Investments in the Rural Branch Railroad and County Road Systems

March 1991

MIDWEST TRANSPORTATION CENTER

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PREFACE

This report is the product of a first-year research project in the University Transportation Centers Program. The program was created by Congress in 1987 to "contribute to the solution of important regional and national transportation problems." A university-based center was established in each of the ten federal regions following a national competition in 1988. Although the centers are interdisciplinary and have educational missions, each has a unique theme and research purpose.

The Midwest Transportation Center (Center) is one of the ten centers; it is a consortium that includes Iowa State University (lead institution) and The University of Iowa. The Center serves Federal Region VII, which includes Iowa, Kansas, Missouri, and Nebraska. Its theme is "transportation actions and strategies in a region undergoing major social and economic transition." Research projects conducted through the Center bring together the collective talents of faculty, staff, and students within the region to address issues related to this important theme.

The project is central to the Center's theme in that it examines the relationship between investment in roads and highways and branch rail lines. The principal investigator was C. Phillip Baumel, a Charles F. Curtiss Distinguished Professor in Agriculture at Iowa State University. He was assisted by Stephen B. Baumhover, Marty J. McVey, and Michael A. Lipsman, all research assistants at Iowa State University.

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EXECUTIVE SUMMARY

The rural transportation system has been undergoing change since the early 1800s. The railroad system grew rapidly in the late 1800s and reached peak mileage in the 1920s. Since then, the miles of track have declined by over 55,000 miles, and more rail line abandonments are expected in the future.

The local rural road system consists of almost 2.2 million miles of paved roads. Most of these roads and bridges were constructed in the late 1800s. Many roads were reconstructed to meet the traffic requirements of the smaller vehicles of the 1940s and 1950s. Rural America, however, has changed dramatically since then, and most of the local rural roads and bridges are inadequate for today's traffic. Furthermore, there are insufficient funds to rehabilitate a system that has been deteriorating for years.

In the past, most public investments in local rural road and branch rail lines were made independent of each other. The purpose of this study was to develop and apply a benefit-cost method of evaluating the tradeoffs between investments in local rural roads and investments in branch rail lines. The method evaluated the impact of local rural road and branch rail line investments on grain revenues to farmers and grain elevators, transport costs for delivery of fertilizer and other farm inputs and outputs, household travel costs for shopping, commuting, deliveries, guests, and other household travel, road maintenance and safety costs, and grain elevator investment costs. The method was applied to a case study of Marshall County, Iowa for the years 1986, 1987, and 1988. Several branch rail line and road investment alternatives were evaluated including:

1. Abandoning the branch rail line from Marshalltown through Green Mountain;
2. Abandoning the branch rail line from Marshalltown through Albion and Liscomb;
3. Construction of a grain train loading elevator west of Marshalltown;
4. Upgrading county road S-75 north of U.S. 30;
5. Paving county road S-75 south of U.S. 30 to county road E-63; and
6. Paving county road S-75 south of E-63 to the Marshall County line.

The study included only traffic that originated or terminated in rural areas and overhead traffic that traveled over the rural roads.

The two rail abandonment solutions yielded contrasting results. In the Green Mountain abandonment, farmer and elevator revenues decreased only slightly. In the Albion-Liscomb abandonment, however, farm and elevator grain revenues dropped substantially; the combined loss in revenue to farmers and elevators was $382,940 and $207,302 in 1987 and 1988, respectively. In

the Albion-Liscomb solution, increased road maintenance costs were more than offset by increases in motor fuel tax collections. Aggregating over the two abandonments, the railroad realized an estimated $300,000 net gain from the salvage value of the two lines and from savings in railroad maintenance costs. Thus, branch line abandonments have significant adverse impacts on farms and farm related businesses, while the railroads gain substantial benefits.

The construction of a unit train grain loading elevator restored all but $35,000 of the lost farm revenues from the two rail abandonments over the three years. The new elevator solution generated $30,000 more revenue to the elevators than was lost in the three years from the two rail abandonment solutions. However, most of the restored elevator revenue accrued to the new elevator. Thus, the major losers from the two rail abandonments and construction of the new elevator were the elevators on the abandoned Albion-Liscomb line and the elevators surrounding the new elevator.

Aggregating all benefits for each road improvement alternative, only the upgrading of S-75 north and the paving of S-75 from U.S. 30 south to E-63 resulted in benefits to farms and households exceeding $20,000 per year. This represented a substantial return to each farm or household expected to use the improved road. However, the cost of making these improvements greatly exceeded the level of benefits. At annualized costs ranging from $106,068 to $427,743 per year, these improvements cannot be justified.

One can conclude that local traffic in Marshall County is not of adequate volume to justify the additional paving of the gravel portion of S-75. Also, the improvement of the already paved S-75 north of U.S. 30 to Albion, by widening lanes and adding shoulders cannot be justified by local traffic and current overhead traffic. However, since the improvement of S-75 north of U.S. 30 would provide an opportunity for additional overhead traffic to bypass Marshalltown, this investment may be justified on the basis of reductions in travel time, operating costs, and accident costs for this rerouted overhead traffic. Since the focus of this study was on the analysis of surface transportation for the purposes of serving rural traffic, the benefits of constructing urban bypasses were not estimated.

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CHAPTER 1

INTRODUCTION

During the last half of the nineteenth century, the westward expansion of the nation's railroad system opened the territory west of the Mississippi River to settlement. As the only efficient mode of long distance transportation, railroads were viewed as a necessity for economic growth and development. The public wanted railroads built, and nearly every town wanted at least one railroad to serve it. To meet public demand, state and local governments actively supported the construction of new railroad lines through right-of-way grants and other direct and indirect subsidies.

The United States railroad system grew rapidly until 1916, with the miles of track peaking at 254,251 miles (Association of American Railroads). Since then, however, more miles of railroad track have been abandoned than have been constructed. In Iowa alone, 7,721 miles of track have been abandoned (Iowa Department of Transportation). A total of 1,621 miles of this abandoned track has been repurchased by other railroads, resulting in a net loss of 6,102 miles of track. By 1988, the miles of railroad track in the United States had declined 31 percent to 174,814 miles (Association of American Railroads). Most of the railroads abandoned, in the United States, have been branch lines serving rural communities.

One reason for the decline of the railroads was the development of the local rural road system, which now consists of 2.2 million miles of paved roads (Baumel, Miller, Pautsch and Hamlett). In the Midwest, most of the rural road system is laid out in rectangular grids. This grid system dates back to the ordinance of 1785, which established the one-mile survey grid and opened the land for settlement.

Many of today's local rural roads and bridges were built in the late 1800s and early 1900s when overland transportation was limited to horse and wagon and recently built railroad lines. By 1950, about half of the local rural roads were improved with all-weather gravel or paved surfaces. The capacities of many of today's local rural roads and bridges are still based on the traffic requirements of the small vehicles of the 1940s and 1950s.

These old traffic requirements present a problem, because farm use of the road system has changed as agriculture has changed. Today, farmers often rent or own land that is dispersed over many miles. Large, and often wide, implements of husbandry are moved over rural roads, resulting in a need for wide bridges capable of carrying heavy loads. Furthermore, grain production and off-farm grain sales have increased dramatically over the past two decades, imposing additional stress on the rural road system. Increasingly, farmers are using large tandem-axle and tractor semi-trailer trucks to haul grain longer distances, to take advantage of higher net prices for their grain. For example, rail abandonment sometimes enables grain elevators located on the remaining rail lines to offer higher grain prices to farmers than elevators that no longer have rail service. The introduction of low cost unit-grain-trains has further widened these grain price differentials. Consequently, rail abandonment and other structural changes in agriculture are encouraging farmers to gain increased revenue by shipping grain farther away, resulting in an increased demand for rural road use.

Analogous to grain movement, rural household travel is changing as well. Changing employment and shopping opportunities in rural areas have placed additional travel on rural roads and highways. Many rural residents commute daily to employment in local towns and cities, and they travel longer distances for shopping and recreation. These travelers demand smooth-surfaced roads which allow high speed travel without damaging today's expensive cars.

Consequently, rural areas continue to need well maintained roads and efficient rail service. At the same time, the shift to larger and fewer farms, accompanied by a declining rural population, means that, in many areas, both the rural road and railroad systems are overbuilt. Yet, the local rural road and railroad systems have been deteriorating for years. Over half of all inventoried off-federal-aid bridges have been rated as structurally unable to carry a legal load limit (U.S. Department of Transportation). Local government officials face the dilemma of their governments being held legally liable for the condition of structures that do not meet reasonable design standards.

At the same time, increased rail abandonment imposes additional traffic on the local rural road system. The Standing Committee on Railroads of the American Association of State Highway and Transportation Officials has called for a comprehensive, surface transportation planning program in stating, "When confronting a transportation issue involving railroads and highways, economic analysis will indicate the most prudent, financial investment strategy. It will determine, for example, whether a rail line should be rehabilitated or a highway should be improved" (American Association of State Highway and Transportation Officials). The report indicates that any future, comprehensive, surface transportation program should develop the ability to anticipate the economic and social impacts of railroad abandonments on shippers, communities, and highways, and should assess the relative benefits of rail and highway system improvements.

OBJECTIVES

The purpose of this research was to develop a methodology that would address rural transportation systems on an integrated basis so that the most efficient use of public funds could be facilitated. The specific objectives were to:

- Develop a transportation system model to evaluate the trade-offs in investments in branch rail lines and local rural roads.
- Test the developed model by applying it to a case study area.
- Identify policy implications for the redirection of public investment in rural surface transportation infrastructure.

The basic purpose of this research is to develop a methodology to integrate branch rail line abandonment and rural road upgrading and abandonment decisions. Therefore, users of these models can, if they wish, use different coefficients than those used in this analysis.

LITERATURE REVIEW

This review of the literature indicates that previous research on rural branch rail line abandonment and on county road investment decisions have not been integrated.

Rail Abandonment

Numerous studies have estimated the impacts of branch rail line abandonment on shippers, communities, and highways. One of the earliest analyses was by Baumel, Miller, and Drinka, which examined the benefits and costs of upgrading 71 branch rail lines in Iowa. The study also estimated the impacts of these rail line abandonments on communities and individual businesses. More recently, Wilson examined the impacts of rail abandonment on communities, shippers, and roads in the Brandon area of Saskatchewan, Canada. Both studies concluded that rail abandonment resulted in major savings in aggregate; and abandonment had only minor impacts on communities, highways, and taxes imposed on local residents.

Another study, by Casavant and Lenzi, developed a procedure to predict the impacts of rail abandonment on roads. This procedure was based on interviews with shippers, who provided information on the quantities of products that would be shipped on branch lines if the lines were not abandoned. In the analysis, these estimated quantities of shipments were trucked from the abandoned branch line shipper locations to a predetermined location on a remaining rail line. These shipments to the other rail lines became the basis for predicting the impacts of rail abandonment on roads. This procedure, however, has two basic problems. First, the procedure does not allow farmers to shift the delivery of grain among elevators. Second, the procedure does not account for fuel taxes paid by the additional trucks to compensate the state and counties for road damage.

Rural Road Systems

Numerous writers have discussed the deteriorating condition of the local rural road and bridge system. However, only a small number of studies, (Fruin; Baumel and Schornhorst; Chicoine and Walzer) have attempted to identify alternative solutions. Fewer still, have attempted to quantify the impacts of deteriorating roads and bridges on travel costs, or the impacts of alternative solutions on travel costs and local government costs.

The Pennsylvania Department of Transportation identified an "Agricultural Access Network" in two Pennsylvania counties. These agricultural access networks included only those roads which were judged to be the most important to the rural areas for transporting agricultural products and supplies to and from farms. In addition, the study identified the key transportation obstructions inhibiting agricultural movements.

Tucker and Thompson examined the impacts of alternative rural road development and maintenance policies on grain marketing costs in southeastern Michigan. The results indicated that grain marketing costs decrease as the road system is improved, but the savings in grain transport costs are far less than the cost of the road improvements.

Tolliver estimated the impacts of grain subterminals--train loading grain elevators that receive grain from farmers and other elevators--on rural highways. Using a spatial interaction model, he found that building a new grain subterminal elevator at Devils Lake, North Dakota would cause minimal short run, system-wide effects on the rural road network.

Two recent studies by Tolliver and Lindamood and by Eusebio and Rindom examined the impact of increased truck traffic on highways following the abandonment of railroad branch lines in North Dakota and Kansas, respectively. Both studies use pavement design formulae developed from the 1961 AASHTO Road Test to allocate highway cost among different classes of vehicles based on typical axle loadings. The weaknesses of this allocation approach are discussed elsewhere in the report.

Rilett, Hutchinson, and Haas examined cost allocation implications on flexible payments. They concluded that the portion of pavement costs attributed to traffic varied from one-quarter to one-third with the remainder attributed to environment degradation.

Several studies, including those by Hartwig, and the Iowa Department of Transportation (1982), have suggested a potential cost savings from the abandonment of local rural roads. Baumel, Miller, Pautsch, and Hamlett were the first to quantitatively evaluate the impacts of alternative local rural road investment strategies on the traveling public and local governments. They incorporated all roads in three 100-square mile areas into a computer program. A benefit-cost analysis was used to evaluate the economics of investment strategies on the low volume, non-paved roads in the three areas. The analysis indicated that only a small number of low volume, non-paved roads could be abandoned with net social benefits. A larger number of these roads could be economically converted to low maintenance roads or private drives. In addition, the analysis indicated negative benefits from upgrading some bridges on low volume, non-paved roads that were posted at less than legal weight limits.

In summary, there have been numerous studies evaluating the impacts of alternative investment strategies on rail branch lines or on rural roads. Most of the studies have concentrated on either railroads or local rural roads. A few have examined the impact of branch rail line abandonment on local rural roads. These studies have generally considered only the impact of grain traffic shifted from rail lines to highways. Moreover, some of the studies assume that all rural road deterioration is caused by increased traffic (axle loadings) and none is caused by environment factors. These latter studies found that rail abandonment resulted in major impacts on local rural roads. However, Rilett, Hutchinson and Haas concluded that only one-quarter to one-third of pavement deterioration costs could be attributed to axle loads and the remainder was caused by environmental degradation.

None of the previous studies evaluated the impacts of railroad abandonment and county road investment decisions on all agricultural traffic (most consider grain traffic only) and on all nonagricultural traffic.

CHAPTER 2

METHOD OF ANALYSIS

A benefit-cost analysis was used to evaluate the trade-offs between investments in branch rail lines and local rural roads. The analysis was conducted on the branch rail lines and paved county roads in Marshall County, Iowa. Marshall County was selected as the case study area for three reasons. First, farmers in Marshall County have numerous grain and livestock marketing options, including nearby truck and barge markets. Second, the county contains a mixture of rural and urban areas. Third, Marshall County has numerous paved county roads and three branch rail lines.

The objective function for each year of the benefit cost analysis is given in Equation (1):

$$NB = \Delta GR_f + \Delta GR_e - \Delta OFTC - \Delta OTC - \Delta PRC - \Delta RRC - \Delta EIC - \Delta SC + \Delta FT, \quad (1)$$

where:

- NB = net societal benefits from railroad and road investment or disinvestment
- GR_f = grain revenues to farmers net of variable transport costs
- GR_e = gross grain revenues to elevators, net of railroad transport costs, and truck transport costs
- OFTC = other variable farm travel costs
- OTC = other variable travel costs
- PRC = paved road construction and maintenance costs
- RRC = branch rail line investment and maintenance costs
- EIC = elevator investment cost
- SC = safety costs
- FT = road fuel tax revenues

The benefit-cost analysis did not attempt to determine the optimal amount of paved county roads or branch rail lines in a study area. Rather, it estimated the impacts of incremental changes to the paved county road network and branch rail line system in the study area.

Details of the models used to estimate the changes in grain revenues and other travel costs are presented in Appendix A. The grain revenue models assumed that farmers and grain elevators are profit maximizers; that is, the farm-to-elevator model assumed that farmers sell grain to the elevator(s) that returned the highest price net of variable transport costs, given the monthly sales patterns and the distributions of vehicles used to deliver grain to elevators. The grain elevator-to-market model assumed that elevators sell grain to the market(s) that yield the highest revenue net of actual rail or truck transport costs given the monthly sales patterns of grain elevators and the markets to which they sold grain. All other travel costs were estimated on a variable cost basis.

Other assumptions in the analysis were:

- Travel costs are a linear function of distance traveled by each vehicle type.
- Motor vehicle purchase decisions are not affected by changes in the road or branch rail line systems.
- Vehicle drivers select travel routes to minimize travel costs.
- Vehicles with gross weights greater than the posted carrying capacity of a bridge cannot cross that bridge.

There were six basic steps used in this analysis. First, Marshall County was divided into two mile by two mile square areas to represent farms. The center of these squares became the origins or destinations for households and farms located within each square. Dijkstra's algorithm was used to determine the minimum cost routes between each origin and each travel destination and between each grain elevator location and each grain market for each vehicle type included in the analysis (Phillips and Garcia-Diaz). Vehicles included in the analysis were automobiles, pickup trucks, single axle, tandem axle, and tractor semi-trailer trucks, and farm tractors and wagons.

The second step used a grain distribution algorithm to estimate the amount of grain shipped from each of the four square mile farms to each elevator by months. Thus, the algorithm maximized grain revenue to farmers by searching out the elevator with the highest bid for each farm net of variable transport costs. It also maximized revenue to elevators by searching out the best bids at grain markets net of actual rail or truck transport costs.

The third step minimized the cost of non-grain shipments to and from farms and household travel for commuting to work, shopping, and other personal trips.

The fourth step determined the impact of each solution on the road system. The total number of vehicle passes was estimated over each road segment to derive estimates for total paved road investment, maintenance, and safety costs.

The fifth step estimated both the investment and maintenance cost savings from abandoning a branch rail line and the annualized cost of constructing a grain train loading elevator.

The last step aggregated the net costs and benefits of alternative investments in branch rail lines and investments in paved county roads.

The following solutions were calculated for the Marshall County study with each succeeding solution containing the changes imposed by the previous solution.

1. Base solution which estimated the cost of all freight and passenger transport costs for 1986, 1987, and 1988 using the rail line and road infrastructure that was in existence in Marshall County on December 31, 1988;

2. Abandonment of the branch rail line from Marshalltown to Green Mountain;

3. Abandonment of the branch rail line from Marshalltown to Albion and Liscomb;

4. Construction of a grain train loading elevator at the intersection of county road S-75 and the Chicago and North Western Transportation Company (hereafter referred to as CNW) main line;

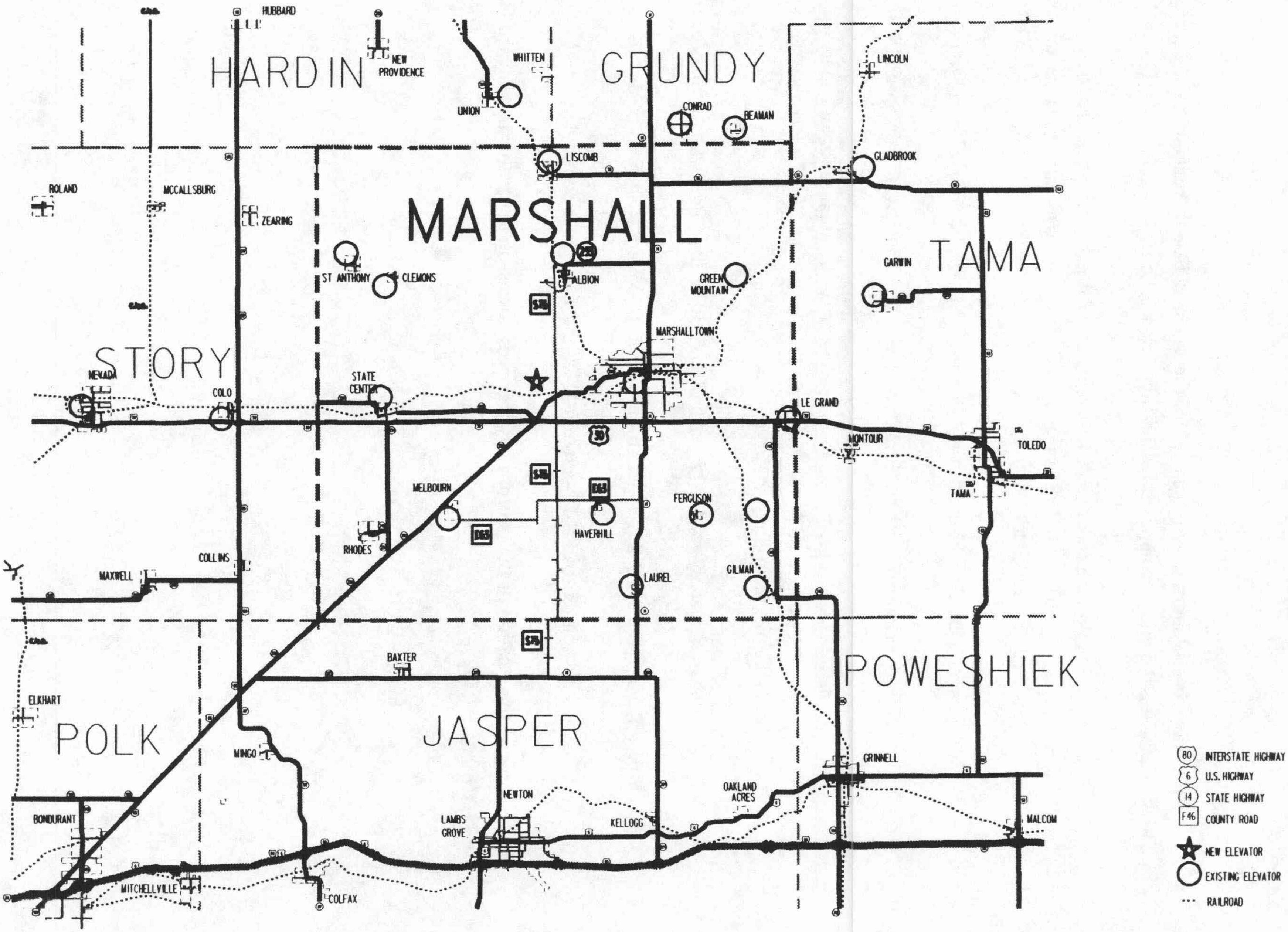
5. Upgrading county road S-75 north of U.S. 30 to Iowa 233, with a bypass of Albion;

6. Paving county road S-75 south of U.S. 30 to county road E-63; and

7. Paving county road S-75 between E-63 and the Jasper county line.

Figure 1 shows the location of the paved roads, railroads, towns, and elevators in Marshall County, Iowa.

FIGURE I
LOCATION OF ELEVATORS, ROADS AND RAILROADS



CHAPTER 3

THE DATA

The data required to evaluate the benefits and costs of alternative branch rail line and paved rural road investments used in this analysis included:

- Quantity of products moving off farms
- Prices bid to farmers by country elevators
- Distribution of vehicles used by farmers to haul grain to elevators
- Prices received by elevators for grain net of actual transport costs at alternative truck and rail markets
- Amount of fertilizer used on farms and the quantity of livestock marketed off farms
- Number of other trips to and from farms by type of vehicle and trip purpose
- Number of trips to and from households by type of vehicle and trip purpose
- Variable travel cost of each type of vehicle except elevator-to-market costs
- Number of overhead trips (i.e., travel through the study area) by road segment
- Cost of constructing new paved county roads
- Salvage value and maintenance cost savings from abandoned rail lines
- Impact of increased motor vehicle travel on highway safety and maintenance costs
- Private investment costs associated with development of a new grain loading elevator
- Monthly distribution of grain sales by farmers to elevators and by grain elevators to processing or export markets

Thus, the data used in this analysis included only traffic that originated or terminated in rural areas as well as overhead traffic that traveled over rural roads. The study does not consider the impacts of shifting traffic away from towns and cities to rural roads.

Quantities of Products Moving Off Farms

The quantities of corn, soybeans, and livestock moving off Marshall County farms and the quantities of fertilizer moving to Marshall County farms were estimated using procedures outlined in McVey, Baumhover, and Baumel. These data are presented in Table 1.

Corn sales were estimated by subtracting estimated quantities of corn fed to livestock from the previous fall harvest. The equation used to calculate Marshall County corn sales is as follows in Equation (2):

$$CS_y = CP_{y-1} - [(\sum_{L} LP_L (FR_L)) - .7691 (OP_{Y-1})] \qquad (2)$$

where:

CS_y = corn sales per year y, y = 1986-1988
CP_{y-1} = corn production for the previous year
FR_L = corn feeding rate for each class of livestock L
OP_{Y-1} = oat production for previous year
LP_L = livestock production for each class of livestock L

Seven livestock classes were used in the model, including milk cows, beef cows, grain fed cows, hogs, hens, pullets, and sheep. Marshall County livestock production data for each class of livestock were taken from the Iowa Agricultural Statistics for the years 1986-1989.

Soybean sales were defined as the residual of the previous year's soybean production less the quantity used for seed. It was assumed that one bushel per acre was the soybean seeding rate. Equation (3) was used to calculate soybean sales:

$$SBS_y = SBP_{y-1} - SBA_y(SR) \quad (3)$$

where:

SBS_y = soybean sales for year y, y = 1986-1988
SBP_{y-1} = soybean production for the previous year
SBA_y = current year soybean acres
SR = seeding rate for soybeans

Fertilizer shipments were taken directly from fertilizer sales reported by the Iowa Department of Agriculture.

Table 1. Estimated Quantities of Commodities Moving From and to Farms, Marshall County, Iowa, 1986-88

Commodity	Units	1986	1987	1988
From farms				
Corn	million bushels	17.0	15.9	13.5
Soybeans	million bushels	3.9	4.2	4.4
Hogs	million pounds	31.0	37.8	48.8
Grain fed cattle	million pounds	16.3	7.9	15.6
Milk	million pounds	9.6	8.4	8.0
Sheep	million pounds	0.3	0.3	0.5
To farms				
Dry fertilizer	thousand tons	19.7	15.7	15.0
Liquid fertilizer	thousand tons	15.7	10.5	12.3

Source: McVey, Baumhover and Baumel and the Iowa Department of Agriculture

Elevator Data

A census of country elevators in and around Marshall County was used to obtain data on:

- Grain prices bid by elevators to farmers;
- Prices bid by grain buyers to country elevators;
- Monthly distribution of grain receipts from farmers by country elevators and shipments by county elevators to markets;
- Distribution of vehicle sizes used by farmers to haul grain to country elevators; and
- Receipts of fertilizer by origin and mode of transport.

Table 2 shows the number of elevators interviewed and the number that provided data. Elevator managers were asked to provide the grain bids they made to farmers and the FOB grain bids they received from buyers net of transport costs for the second Wednesday of each month during 1986, 1987, and 1988. Two bid prices were obtained in October to provide a better reflection of price response during this harvest month. Of the 25 elevators interviewed, one failed to provide any grain bids to farmers and three failed to provide bids they received from market buyers. Most elevators had some missing price data. Bids from a nearby elevator were used as substitutes for any missing price data.

Table 2. Number of Grain Elevators Providing Information

	In Marshall County	Surrounding Marshall County
Interviewed	18	7
Provided:		
grain bids to farmers	17	7
grain bids from markets	15	7
grain receipt-shipment data	17	6
fertilizer receipt-shipment data	13	6

Table 3 shows the percent of corn and soybean receipts at country elevators by months. Except for corn in 1988, total country elevator receipts were highest in October.

Table 3. Percent of Corn and Soybean Receipts at All Interviewed Country Elevators by Months, 1986, 1987 and 1988

	Corn			Soybeans		
Month	1986	1987	1988	1986	1987	1988
January	3.6	5.2	6.2	5.6	4.0	4.9
February	3.6	3.0	5.4	3.9	3.8	5.0
March	4.2	3.7	8.5	4.8	4.0	6.8
April	4.4	6.9	4.3	3.7	7.2	5.9
May	3.4	5.1	6.6	9.7	7.0	6.8
June	5.7	5.4	10.8	6.3	6.9	11.0
July	7.3	4.6	8.9	5.6	4.2	11.0
August	8.9	7.8	11.2	8.2	7.2	8.7
September	14.9	18.4	17.9	15.1	14.0	8.5
October	25.6	32.0	10.8	18.1	18.7	12.3
November	15.9	5.4	3.1	14.5	10.0	11.1
December	2.5	2.5	6.3	4.5	13.0	8.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Elevator survey

Corn and soybean prices bid to farmers for selected dates in 1986, 1987, and 1988 at one Marshall County country elevator are shown in Table 4. Bid prices declined sharply in mid-1986, remained relatively stable in 1987, and increased sharply in mid-1988.

Table 4. Corn and Soybean Prices Bid to Farmers at One Marshall County Elevator 1986, 1987, and 1988

	Corn			Soybeans		
Dates	1986	1987	1988	1986	1987	1988
Mid-January	$2.28	$1.38	$1.72	$5.10	$4.68	$5.77
Mid-February	2.26	1.24	1.81	5.09	4.53	5.98
Mid-March	2.22	1.40	1.75	5.18	4.63	5.81
Mid-April	2.22	1.48	1.79	5.08	4.84	6.38
Mid-May	2.36	1.65	1.89	5.08	5.31	7.20
Mid-June	2.27	1.71	2.46	5.14	5.50	8.62
Mid-July	1.86	1.50	2.80	5.05	5.15	8.50
Mid-August	1.52	1.28	2.55	4.81	4.86	8.50
Mid-September	1.15	1.42	2.62	4.80	5.03	8.46
Early October	1.33	1.44	2.63	4.60	5.01	7.83
Late October	1.12	1.48	2.59	4.36	4.90	7.65
Mid-November	1.45	1.68	2.35	4.70	5.28	7.16
Mid-December	1.43	1.63	2.45	4.57	5.45	7.45

Source: Elevator survey

Table 5 shows the percent of corn and soybean shipments by country elevators by months. February and March were the low shipping months for corn. The peak shipping periods were during the harvest months with 30-45 percent of the corn shipped during September, October, and November. The late summer months were the slow shipping periods for soybeans as processors reduced their supplies in anticipation of the new crop harvest.

Table 5. Percent of Corn and Soybean Shipments by Country Elevators, By Months, 1986, 1987, and 1988

	Corn			Soybeans		
Month	1986	1987	1988	1986	1987	1988
January	6.2	4.4	5.4	9.1	6.6	11.6
February	4.1	4.4	4.5	7.4	6.6	11.9
March	4.3	4.2	6.8	11.4	8.2	12.3
April	5.3	8.0	7.9	9.2	4.3	15.0
May	8.1	6.9	8.5	6.5	7.5	6.9
June	5.9	7.5	10.0	6.8	11.4	9.0
July	7.5	5.6	10.3	6.2	8.5	5.6
August	9.0	7.2	9.5	4.2	5.3	5.1
September	14.3	12.4	9.1	5.0	6.2	5.3
October	17.7	17.8	10.0	14.1	16.1	7.9
November	13.3	9.7	10.1	10.5	10.1	6.1
December	4.3	11.9	7.9	9.6	9.2	3.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Elevator survey

Table 6 shows the percent of country elevator grain receipts by type of vehicle. Seventy percent of the grain receipts were by truck and 30 percent by tractor wagons. Single axle, tandem axle, and tractor semi-trailer trucks were assigned loads of 300, 600, and 900 bushels of grain, respectively.

Table 6. Percent of Grain Receipts at Country Elevators by Type of Vehicle

Vehicle type	Percent
Trucks	
Single axle	32
Tandem axle	29
Tractor semi-trailer	9
Tractor-wagon	
One--300 bushel	20
Two--300 bushel	10

Source: Elevator survey

Table 7 shows the market destinations of the various classes of livestock and milk sold off Marshall County farms. Hogs and cattle were assumed to be delivered to markets in tractor semi-trailer trucks, sheep in pickup trucks, and milk in tandem-axle bulk tank trucks.

Table 7. Market Destinations of Livestock and Milk Sold From Marshall County Farms

	Market	
Livestock class	Location	Percent
Hogs	Marshalltown, Iowa	75
	Perry, Iowa	25
Cattle	Tama, Iowa	50
	Des Moines, Iowa	30
	Joslin, Illinois	20
Milk	Des Moines, Iowa	100
Sheep	Colfax, Iowa	100

Source: Iowa State University Extension Staff

Fertilizer Receipts

Tables 8 and 9 show the percent of liquid and dry fertilizer receipts by Marshall County fertilizer dealers by origin and mode of transport. Trucks dominated the transport of both liquid and dry fertilizer to dealers. Between 70 and 90 percent of the liquid fertilizer and 75 to 80 percent of the dry fertilizer was delivered to dealers by truck. Railroads delivered the remainder. The major sources of trucked, liquid fertilizer were Marshalltown and Green Mountain, while the major source of rail delivered, liquid fertilizer was Saskatchewan, Canada. The major source of trucked, dry fertilizer was Nevada, Iowa, located about 30 miles west of Marshalltown.

Table 8. Percent and Total Tons of Liquid Fertilizer Receipts at Fertilizer Dealers, by Origin, Mode of Transport, and Year

	1986		1987		1988	
Origin	Truck	Rail	Truck	Rail	Truck	Rail
Marshalltown, Iowa	33.8	--	28.1	--	42.0	--
Fort Dodge, Iowa	5.3	--	6.1	--	6.8	--
Eldora, Iowa	4.6	--	4.5	--	1.1	
Green Mountain, Iowa	14.4	--	16.8	--	20.7	--
Durant, Iowa	6.0	--	7.0	--	8.7	--
Nevada, Iowa	1.8	7.8	2.3	8.8	--	--
Saskatchewan, Canada	--	16.6	--	20.5	--	10.2
Other	8.8	0.9	4.9	1.0	10.5	--
Total	74.7	25.3	69.7	30.3	89.8	10.2
Total tons	15,727		10,516		12,318	

Source: Elevator survey

Table 9. Percent and Total Tons of Total Dry Fertilizer Receipts at Fertilizer Dealers, by Origin, Mode of Transport, and Year

Origin	1986 Truck	1986 Rail	1987 Truck	1987 Rail	1988 Truck	1988 Rail
Marshalltown, Iowa	4.0	9.6	4.7	7.2	4.5	7.5
Fort Dodge, Iowa	2.7	--	--	--	--	--
Eldora, Iowa	5.7	--	--	--	--	--
Green Mountain, Iowa	13.3	--	14.0	--	11.7	--
Durant, Iowa	0	--	--	--	1.9	--
Nevada, Iowa	51.3	--	51.5	--	58.4	--
Saskatchewan, Canada	3.6	--	4.8	3.2	2.2	3.0
Other	--	9.6	--	14.6	--	11.3
Total	80.8	19.2	75.0	25.0	78.2	21.8
Total tons	19,711		15,729		14,955	

Source: Elevator survey

Other Travel

There was insufficient funding and time to conduct a survey of non-agricultural commodity travel for this analysis. However, a survey of these types of travel had been made in Hamilton, Linn, and Shelby counties in Iowa in 1982 (Baumel, Hamlett and Pautsch). The Linn County trip data were judged to be a closer approximation to Marshall County trips than trips from the other two counties.

Therefore, the Linn County data were used to estimate Marshall County trips in the following manner:

1. The Linn County study area was divided into two areas--those areas surrounding urban communities and the remaining rural areas. Then the Linn County data were categorized into the following groups: (1) farm-related deliveries and visitors, (2) household-related visitors and deliveries, (3) shopping, and (4) commute-to-work trips.

2. The estimated average number of Marshall County farm-related trips per farm was based on the number of Linn County trips per farmable acre while the number of Marshall County household-related trips per household was based on the number of Linn County trips per household. The number of Marshall County trips was estimated by multiplying the average trips per household and per farm by the number of households and farmable acres per farm, respectively. These estimated trips are presented in Table 10.

The number of hired help and customer trips were very high in the urban areas, because there were more households per farmable acre in these areas than in the rural areas. Moreover, many jobs performed by household members in rural areas are hired out by households in the urban areas.

Table 10. Estimated Number of Farm and Household Related Trips Per Year in 2 x 2 Miles by Urban and Rural Areas of Marshall County

	Average number of trips	
	Rural	Urban
Farm-related trips per 2 x 2 mile section		
Seed delivery	3	1
Hired help	45	459
Customer	39	120
Other	0	3
Household-related trips per household		
Deliveries		
Fuel	5	4
UPS	5	7
Coal	1	1
Other	14	25
Sales representatives	14	5
Repair	3	3
Guests	81	59

Source: Baumel, Miller, Pautsch and Hamlett

3. Shopping trips from the Linn County survey were converted to Marshall County estimates on the basis of the number of shopping trips per household per year. The destination of these estimated Marshall County trips were based on Marshall County retail sales tax collection data. Table 11 shows the estimated Marshall County sales tax collection data. Since Marshalltown collected tax on 90 percent of total county retail sales, 90 percent of all shopping trips were assumed to go to Marshalltown and the remaining 10 percent to the town closest to the 2 x 2 mile farm area.

4. Work commuting trips from the Linn County data were converted to Marshall County data based on the number of commuter trips per year per household. The destinations of the estimated commuter trips per household were based on the location of the manufacturing jobs per Marshall County community. Table 12 shows

Table 11. Retail Sales Tax Collections for Marshall County, 1987

City	Amount	Percent
Marshalltown	$210,698	90.2
Melbourne	1,221	0.5
Gilman	1,627	0.7
Albion	1,219	0.5
State Center	4,059	1.8
Laurel	979	0.4
Other	13,895	5.9
Total	$233,698	100.0

Source: Manufacturers News, Incorporated

the number and percent of total 1987 manufacturing jobs by location in Marshall County. Marshalltown had 95 percent of the Marshall County manufacturing jobs. Therefore, 95 percent of the commuting trips were assigned to Marshalltown and the remainder were assigned to the town closest to each 2 x 2 mile area.

Table 12. Location of Marshall County Manufacturing Jobs, 1987

Location	Total	Percent
Marshalltown	5,583	94.7
Gilman	38	0.6
Liscomb	14	0.2
Ferguson	15	0.3
Haverhill	10	0.2
LeGrand	150	2.5
Melbourne	10	0.2
State Center	27	0.5
Albion	50	0.8
Total	5,897	100.0

Source: Manufactures News, Incorporated

Calculation of Variable Costs Per Vehicle

Variable vehicle travel costs were used for all vehicles in this study except for those transporting grain from elevators to markets. Actual rail and truck rates were used for elevator to market grain shipments because the grain bids to elevators from each market were Free on board (FOB). FOB bids are the bids to elevators net of actual rail and truck freight rates.

Variable vehicle travel costs were used for all other trips for four reasons. First, this analysis focused on the cost of the additional travel required to adjust to changes in the railroad and highway system; that is, the analysis assumed that the products to be hauled are already loaded and unloaded on existing trucks regardless of the destination of the products. All passenger travel was assumed to be made in existing vehicles regardless of changes in the road network.

Secondly, there is substantial overcapacity in on-farm trucking capacity. For example, one farmer customer of the elevator which is managed by a member of the advisory committee for this study owns two tandem-axle trucks. In one day in 1990, this farmer delivered 14,473 bushels of corn a distance of 4 miles from his farm to the elevator in one 6-hour period. Each trip required a total of 30 minutes of which 57 percent of the time was for loading and unloading. This farmer, who produces about 130,000 bushels of corn and soybeans annually, could deliver his entire crop to the elevator in a total of about 55 hours. Thus, these two trucks are available for other uses or for hauling longer distances for more than 50 weeks per year. The major reasons that farmers have excess trucking capacity are to haul grain from the combines to farm storage or to elevators during the three to four week harvest period and to take advantage of immediate delivery markets, sometimes referred to as inverted markets.

Third, most farm trucks do not wear out from travel because they accumulate so few miles. Rather, the reasons for replacing farm trucks are typically to upgrade to larger trucks or because the trucks are simply "beat up" from on-farm use.

Fourth, when farm-to-elevator grain is hauled by commercial truckers--frequently by farmers who hire out their trucks for commercial haulage--the additional miles, excluding loading and unloading, is often priced on a variable cost basis. Commercial trucker quotes for hauling grain from Iowa origins to Iowa markets in mid-1990 were approximately $1.00 per loaded mile. These quotes are slightly below the loaded and unloaded variable cost estimates for tractor semi-trailer trucks in Table 13.

Once the different trip types were identified, it was necessary to calculate the variable operating costs for each vehicle. The state highway and gravel road variable vehicle operating costs were based on cost estimates taken from Baumel, Hamlett and Pautsch. The truck and tractor-wagon costs were adjusted from the Baumel data to reflect increased fuel, oil, and farm labor costs. The automobile and pickup variable costs were not adjusted from the Baumel data, based on the assumption that the operating cost savings of lighter, more fuel efficient vehicles offset the increased cost of fuel, oil, and driver's time.

Table 13 shows the variable cost per vehicle mile for each type of vehicle in this analysis. Travel on primary roads (state highways) was assumed to be faster than on county roads because of wider lanes and shoulders, lesser grades, and smoother curves. Therefore, the variable cost for registered vehicles was lower on state highways than on paved county roads because of an assumed faster speed of five miles per hour on state roads.

Table 13. Estimated Variable Cost Per Vehicle Mile & Road Type in Cents Per Mile

	Type of road		
	State	Paved county	Gravel
Auto/pickup	20.19	21.60	28.05
Trucks			
Single axle			
empty	47.4	49.7	69.2
loaded	48.0	50.4	70.8
Tandem axle			
empty	52.2	54.8	77.3
loaded	54.5	57.3	80.6
Tractor semi-trailer			
empty	48.6	51.0	70.9
loaded	52.5	55.1	76.6
Tractor-wagon			
One--300 bushel	127.0	127.0	148.5
Two--300 bushel	159.7	159.7	186.9

Source: Adjusted data from Baumel, Miller, Pautsch and Hamlett

Railroad Savings From Branch Line Abandonment

Rail branch line abandonments create savings to the railroad from the following sources: (1) salvage value of land and materials; (2) maintenance costs; and (3) safety and liability costs.

Table 14 shows the salvage values of the branch lines from Marshalltown to the county line via Green Mountain and from Marshalltown to the county line through Albion and Liscomb. All investments in this analysis were annualized by a capital recovery formula (White, White and Case) using a 7.0 percent interest rate. The 7.0 percent interest rate was chosen to make this study consistent with previous Iowa Department of Transportation road and railroad studies.

Avoidable maintenance costs were taken from abandonment applications filed by the CNW for the entire Green Mountain line and for a portion of the Albion-Liscomb line north of Marshall County. These costs were prorated on a track mile basis for each of the two lines evaluated in this analysis. These prorated costs are presented in Table 15. Only 1986 data were available for the Green Mountain line, and only 1986 and 1987 data were available for the Albion-Liscomb line. No data were available to estimate railroad safety and liability cost on the two branch rail lines.

Table 14. Estimated Total and Annualized Salvage Values of the Green Mountain and Albion-Liscomb Branch Lines

Item	Marshalltown through Green Mountain		County line through Albion-Liscomb to Marshalltown	
Miles of line	12.2		15	
Value of rail, ties, and other materials	$945,199		$1,074,545	
Less salvage expenses	98,088		120,600	
Net value of material		$847,111		$953,945
Land				
Acres	148		182	
Value/acre	$ 500		$500	
Land value		74,000		91,000
Total salvage value		$921,111		$1,044,945
Annualized value of materials over 15 years		93,013		104,743
Annualized value of land		5,180		6,370
Total annualized value		$ 98,193		$111,113

Source: Nelson

Table 15. Estimated Avoidable Maintenance Costs From Abandonment of the Green Mountain and Albion-Liscomb Branch Rail Lines by Years

	Avoidable maintenance costs	
Year	Green Mountain Line	Albion-Liscomb Line
1986	$49,021	$41,941
1987	49,021	37,681
1988	49,021	37,681

Source: Interstate Commerce Commission, June 30, 1988 and August 26, 1988

ESTIMATED ROAD IMPROVEMENT COSTS

Road Improvement Costs

Marshall County road S-75 was upgraded in this study to evaluate the potential impact of branch railroad line abandonment and the construction of a new unit train loading grain elevator on the county road system. The improvement of this road was selected for study because it parallels the Marshalltown to Liscomb branch railroad line, which is the main grain gathering branch line in Marshall County. Also, this road provides the most direct access to the site identified as having the greatest potential for a new elevator subterminal. The improvement of S-75 was considered in three increments: (1) 8.5 mile segment from U.S. 30 north to Iowa 233, including a bypass of the city of Albion; (2) 4 mile segment from U.S. 30 south to county road E-63; and (3) 6 mile segment from E-63 south to the Jasper County line.

From U.S. 30 north, county road S-75 is already paved with asphalt concrete (AC) and carries about 2,000 vehicles per day. This road segment, along with Iowa 233, currently serves as a bypass of Marshalltown. In addition, if the Marshalltown to Liscomb railroad branch line was abandoned and a new unit train loading grain elevator is built on the CNW main line, this road segment could be expected to carry increased truck traffic. Therefore, the analysis assumes the road will need to be reconstructed to primary highway standards with a bypass of Albion to improve traffic flow.

County road S-75 is gravel from U.S. 30 south and carries only from 20 to 140 vehicles per day. The highest traffic levels are just south of U.S. 30 and the lowest are just north of the Jasper County line. The principal break in traffic occurs at paved county road E-63. For this reason, S-75 south of U.S. 30 was divided at E-63 into two segments for analysis. In the analysis, these two segments of S-75 south of U.S. 30 were upgraded to county road standards. Descriptions of existing road conditions and proposed improvements for the three segments of county road S-75 are presented in Table 16. No other major improvements to the rural road system were considered in this analysis.

Other paved county roads in Marshall County in the vicinity of the Marshalltown to Albion railroad line carry an average of about 500 vehicles per day; less than 15 percent of the total are trucks. Typical design standards for flexible pavement county roads specify a 6 inch aggregate subbase, a 4 inch asphalt stabilized base course and 2 inch AC surface course. Based on normal traffic and traffic mix, a road built to this standard would be expected to have a 40-year life before requiring resurfacing (Jesse). However, the typical length of time between resurfacings is only 15 to 20 years. Therefore, a moderate increase in truck traffic, 8 to 10 trips per day, evenly split between loaded and empty, would not be expected to result in an acceleration of the need to resurface county roads.

Similarly, since state primary roads are constructed to higher standards than county roads, moderate increases in truck traffic resulting from a railroad abandonment would not be expected to accelerate their normal pavement rehabilitation and reconstruction cycle. For example, truck traffic on U.S. 30 would have to nearly double to result in an acceleration of pavement resurfacing. Given the amount of additional traffic diverted to S-75 as a result of either the Marshalltown to Liscomb railroad line abandonment and the construction of a new grain subterminal elevator, no

Table 16. Estimated S-75 Road Improvement Requirements and Costs in Marshall County

	S-75 Road Segment		
	U.S. 30 to I.A. 233	U.S. 30 to E-63	E-63 to county line
Current condition	Paved AC*	Gravel	Gravel
Length (miles)	8.5	4	6
Improvement			
Reconstruction (miles)	6.75	0	0
New construction (miles)	1.75	4	6
Type of improvement			
Width of lanes	12-foot PCC*	12-foot PCC	12-foot PCC
Width of shoulders	8-foot granular	6-foot earth	6-foot earth
Cost			
Right of Way			
@ $2000 acre	$ 33,000	$ 32,000	$ 48,000
New construction			
@ $540,000 per mile			
S-75 North	998,000	0	0
@ $308,400 per mile			
S-75 South	0	1,233,600	1,850,400
Reconstruction			
@ $570,000 per mile	3,848,000	0	0
Bridges	245,000	0	0
Engineering	775,400	197,400	296,100
TOTAL	$5,899,900	$1,463,000	$2,194,500
Annualized construction cost @ 7% and 50 years	$ 427,743	$ 106,068	$ 159,101

* AC refers to asphalt concrete and PCC refers to Portland Cement Concrete.

Source: Iowa Department of Transportation, 1983

other roads would be sufficiently affected as to require reconstruction.

Other studies, such as those by Eusebio and Rindom for Kansas and by Tolliver and Lindamood for North Dakota, conclude that railroad abandonment results in substantial increases in highway construction and maintenance costs. However, these studies both ignore the effects of weather and drainage conditions on road deterioration. Moreover, they assume the pavement deterioration is a function of use as measured by Equivalent Standard Axle Loadings (ESALs). The paved county road system is generally built to standards generally exceeding what is needed to serve normal levels of traffic (Fitchner). Therefore, small increases in truck traffic will not induce sufficient added wear to require the acceleration of pavement rehabilitation or reconstruction. The exception would be near major traffic concentration points such as at entrances to grain elevators and major highway junction points.

Highway Maintenance Costs

The purpose of this analysis was to evaluate the impacts of railroad and county road investments on traffic flows and costs. Therefore, only variable road maintenance costs were estimated. Variable road maintenance costs include repairs on pavements, shoulders, bridges, striping and marking, traffic control and resurfacing. These costs represent approximately 10-40 percent of total maintenance costs. Non-variable maintenance costs consist of overhead costs--administration, equipment, building and land maintenance, training, and leave--and common costs--drainage, spraying, signing, snow and ice removal, litter cleanup, and several other road maintenance activities.

Variable maintenance costs were allocated among vehicle types based on the ESAL for each vehicle type. ESALs are a common denominator for expressing the pavement damage resulting from axle loads of different magnitudes (different weights). The damage done by one 18,000 pound load is considered one ESAL. A loading of less than 18,000 pounds is less than one ESAL and loading heavier than 18,000 pounds is more than one ESAL. However, the relationship between axle loadings and ESALs is non-linear and standard conversion tables are taken from Baumel, Miller, and Drinka.

The number of round trip passes in the life of each pavement type by vehicle type was obtained by dividing the number of 18,000 loads in the life of the pavement by the number of ESAL corresponds to each vehicle. It was assumed that there are 23,523,000 passes in the life of a rigid pavement and 808,000 passes in a flexible segment. Finally, after obtaining the number of round trip passes in the life of the highway by vehicle type, variable maintenance costs per mile for rigid and flexible pavements was computed by vehicle type as follows in Equation (4):

$$MCMVT_i = (CRTM_i \times CAF_{MC})/RPVT_i \qquad (4)$$

i = 1,2
1 = flexible pavement
2 = rigid pavement

where:

$MCMVT_i$ = maintenance cost per mile, by vehicle type, on road type i
CRTM = cost per round trip mile on pavement type i
CAF_{MC} = cost adjustment factor for Marshall County
$RPVT_i$ = number of round trip passes, by vehicle type, in the life of the highway on pavement type i

Table 17 shows the estimated variable maintenance costs per mile, by vehicle type, for empty and loaded passes.

Table 17. Estimated Variable Maintenance Costs by Vehicle and Pavement Types in Cents Per Mile

Vehicle type	Vehicle status	Type of pavement Rigid	Flexible
Automobile		0.00007	0.00022
Trucks			
Single axle	Empty	0.0011	0.03
	Loaded	0.14	3.95
Tandem axle	Empty	0.0027	0.074
	Loaded	0.27	6.91
Semi	Empty	0.0052	0.131
	Loaded	0.51	13.08
Farm tractor			
One wagon	Empty	0.005	0.20
	Loaded	0.039	1.086
Two wagons	Empty	0.015	0.395
	Loaded	0.075	1.925

Highway Safety Costs

The accident cost per vehicle mile was estimated by the following Equation (5):

$$ACM = \frac{ACY}{TVMT} \quad (5)$$

where

ACM = average accident cost per mile
ACY = average total accident cost per year
TVMT = average total vehicle (car and truck) miles traveled per year

Average accident costs per vehicle mile were calculated from data on truck accident costs and vehicle miles traveled obtained from the Iowa Department of Transportation for the years 1986-1988. Table 18 shows the average accident cost per vehicle mile for selected state routes in Marshall County. Accident cost data were not available for gravel county roads.

The accident cost per mile was multiplied by the change in traffic miles for all vehicles for each road segment in each solution. Estimated accident costs for U.S. 30 were used for Iowa 330, Iowa 96 accident costs were used for S-75, Iowa 14 accident costs were used for high volume county roads (2,000+ ADT), and Iowa 146 accident costs were used for low-volume county roads (less than 2,000 ADT).

Table 18. Estimated Average Accident Cost for Selected State Roads in Marshall County 1986-1988 in Cents Per Mile

State highway	Accident cost in cents per mile
U.S. 30	5.11
Iowa 96	5.54
Iowa 14 south of Marshalltown	1.56
Iowa 14 in Marshalltown	2.96
Iowa 146	2.48
S-75 north of 30	7.88

Source: Iowa Department of Transportation, Bureau of Transportation Safety

New Elevator Construction Costs

A new elevator constructed in the model at the intersection of county road S-75 and the CNW mainline railroad track was assumed to have the following capacities: (1) 400,000 bushels of storage; (2) 20,000 bushels per hour receiving capacity; (3) 25,000 bushels per hour load out capacity; and (4) railroad siding to handle a 75-car unit grain train. The total cost of this facility was estimated to be $1,494,880. Estimates of total and annualized costs by elevator component are presented in Table 19.

Road Use Tax Revenues

Registered motor vehicles are assessed a variable road use tax which is paid as a fuel tax at the fuel pump. Therefore, this tax is paid on any additional miles traveled resulting from changes in the railroad or county road system and can be used to offset investments in roads. The additional taxes paid per mile traveled were calculated by dividing the change in vehicle miles for each vehicle type by the miles per gallon of fuel for each vehicle type. This yields the change in the number of gallons of fuel used by each vehicle type. The change in the number of gallons used by each vehicle type was multiplied by the respective fuel tax per gallon to obtain an estimate of the total additional fuel taxes paid. Table 20 shows the per gallon fuel tax by years.

Table 19. Estimated Installed and Annual Costs For a 400,000 Bushel Train Loading Elevator

Cost item	Depreciation years	Purchase cost	Annualized cost
Storage			
Steel tanks and concrete storage	40	$480,000	$36,000
Aeration and heat detection equipment	10	46,920	6,681
Conveyers	10	32,640	4,648
Land	--	25,000	1,750
Receiving			
Scale house	20	19,800	1,869
Truck scales	20	30,300	2,860
Sampler, tester, etc.	5	5,760	1,405
Driveway & truck hoists	20	89,520	8,451
Dump pits	30	46,320	3,733
Conveyer in pits	10	19,320	2,751
Legs	10	62,520	8,903
Distributors	10	18,660	2,657
Conveyers & gates	10	16,920	2,409
Manlift	10	9,120	1,299
Spouting & misc.	5	16,200	3,951
Load out			
Rail siding & switches	40	360,330	27,028
Track mobile	15	48,000	5,270
Scales	20	53,850	5,083
Load out legs & belts	10	82,530	11,752
Cleaners	10	13,020	1,854
Spouts & misc.	5	18,150	4,427
Total		$1,494,880	$144,781
Insurance and taxes @ 3.8 percent			56,805
Total annual cost			$201,582

Source: Van Der Kamp

Table 20. Motor Fuel Tax Rates in Cents Per Gallon, Iowa, 1986, 1987, and 1988

	Cents per gallon	
Year	Gasoline	Diesel
1986	16	17.5
1987	16	18.5
1988	17	19.5

Source: U.S. Department of Transportation, Highway Statistics, 1986, 1987 and 1988

Table 21 shows the estimated miles per gallon by vehicle type. No fuel taxes were assumed to be paid by farm tractor-wagons hauling grain from farms to elevators.

Table 21. Estimated Miles Per Gallon of Fuel by Vehicle Type

Vehicle type	Estimated miles per gallon
Automobile	18.0
Trucks	
Single axle	7.2
Tandem axle	5.6
Tractor semi-trailer	5.6

Source: Baumel, Hamlett and Pautsch

CHAPTER 4

RESULTS

Seven alternative railroad and county road solutions estimated in this analysis are:

1. **Base solution** that: (a) maximized 1986, 1987, and 1988 net revenue to farmers for the sale of their corn and soybeans to elevators; (b) maximized net revenues to elevators for the sale of their corn and soybeans to the markets; (c) minimized the travel costs of delivering other products to and from farms; and (d) minimized travel costs of all household and estimated overhead traffic to move on the Marshall County road network during the same three years.

2. **Abandonment of the Marshalltown-Green Mountain branch rail line.** The computer model was modified to reflect the abandonment of the Marshalltown to Green Mountain branch rail line. This was accomplished in the grain models by eliminating the rail grain bids to elevators located on abandoned rail lines. Then, the full model was reestimated.

3. **Branch rail line from Marshalltown through Albion and Liscomb was abandoned.** This was accomplished by eliminating the rail grain bids to the elevators on the abandoned rail line. The Marshalltown-Green Mountain rail line remained abandoned in this solution.

4. **Grain train loading elevator was constructed** at the intersection of the CNW mainline and county road S-75. The Green Mountain and Albion-Liscomb lines remained abandoned.

5. **County road S-75 north of U.S. 30 was reconstructed** with a rigid pavement. The Green Mountain and Albion-Liscomb lines remained abandoned and the new elevator in Solution 4 continued to operate.

6. **County road S-75 was constructed** with rigid pavement south of U.S. 30 to county road E-63. All previous changes to railroad and highway network remained in the model.

7. **County road S-75 was constructed** with a rigid pavement south of country road E-63 to the county line. All previous changes to the railroad and highway network remained in the model.

FARM-TO-ELEVATOR GRAIN FLOWS

Tables 22, 23, and 24 show the estimated quantities of corn and soybeans received by elevator locations for 1986, 1987, and 1988 from the computer model in each of the seven solutions. A discussion of the impact of each solution on farm-to-elevator grain flows follows.

(1) Base Solution

The three grain train loading elevators--Liscomb, Pickering, and Union--received 32, 50, and 25 percent of the 1986, 1987, and 1988 corn and soybean receipts, respectively. The principal reason for these large shares was the higher prices they offered to farmers because of the lower elevator-to-market rail transport rates and access to markets provided by their unit train service. The 50 percent share in 1987 indicates that bids at rail markets (Clinton) were relatively higher than bids at truck markets (Cedar Rapids and Des Moines) in that year. Three non-train loading elevator locations--Marshalltown, Melbourne, and Garwin--also received large shares of the total receipts, particularly in 1986 and 1988. Together, these three locations received 40, 20, and 39 percent of the total bushel receipts in 1986, 1987, and 1988, respectively. These three elevators bid high grain prices to farmers even though they did not have access to unit trains. In 1986, these six elevator locations received 71 percent of the grain and the other 15 elevator locations, nine in Marshall County and six elevators outside of Marshall County, received the remaining 29 percent of the grain. This concentration of grain receipts indicates that the model is very sensitive to price changes among elevators and years.

Figures 2 and 3 show the modeled flow of corn from 2 mile x 2 mile farms in a tractor and one wagon combination for June and September 1988. June and September were selected to show changes among harvest and non-harvest months. Figures 4 and 5 show the modeled corn flows in tractor semi-trailer trucks for the same months.

Almost all elevators received corn in the tractor-wagon combination because the high variable delivery cost in this vehicle type encourages delivery to the closest elevator. Moreover, the direction of corn flows in tractor-wagons remained relatively constant in June and September because the high cost per bushel mile of this vehicle prohibits farmers from responding to many competing elevator grain bids.

Tractor semi-trailer truck corn deliveries were concentrated at the high grain bid elevator locations. These deliveries changed sharply between the two months. In the pre-harvest month of June 1988, all of the corn delivered by tractor semi-trailer trucks was received by the elevators at Marshalltown because they had the highest corn bid for that month. However, in the harvest month of September, all of the corn delivered by tractor semi-trailer truck was delivered to the

Table 22. Estimated Change in Bushels of Corn and Soybeans Received by Elevator Locations From the Previous Solution in Thousands of Bushels, 1986

		Change from previous solution					
Elevator location	Base solution	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
Albion	1,852.7	0	-1,172.2	-163.3	-57.6	-32.4	0
Clemons	138.9	0	86.0	-41.5	-14.6	-1.4	0
Ferguson	145.2	0	14.0	-26.7	-28.2	-14.3	0
Gilman	112.4	0	9.9	0	-22.9	0	0
Green Mountain	386.1	0	124.6	-13.4	-111.1	-0.7	0
Haverhill	385.2	0	28.8	-44.5	-36.2	68.8	6.0
Laurel	1,068.0	0	14.8	0	-79.8	-27.2	-6.1
Le Grand	270.1	0	216.7	-46.5	-108.1	4.0	-0.9
Liscomb	2,418.5	0	-1,799.7	-45.5	-110.1	1.8	0
Marshalltown	2,816.9	6.7	464.3	-379.3	192.5	-10.6	6.8
Melbourne	761.2	0	224.6	-229.8	-46.8	-50.4	-18.5
Pickering	2,154.6	0	885.5	-168.7	239.8	-10.1	-22.1
St. Anthony	539.1	0	46.3	-32.2	199.3	2.6	0
State Center	167.5	0	163.2	-44.2	-120.6	9.6	2.7
New Elevator	--	-	--	2,201.0	-18.6	109.8	16.3
Surrounding Marshall County							
Beaman	232.0	3.1	95.5	-1.7	-63.8	0	0
Colo	161.5	0	33.8	-15.9	-40.0	-16.5	0
Conrad	85.6	0	122.9	-9.5	-53.8	-3.4	0
Garwin	4,767.0	0	1,372.9	-875.2	201.5	-22.2	15.8
Gladbrook	148.5	-9.8	0	0	99.9	0	0
Union	2,176.9	0	-936.9	-40.8	-20.6	-2.2	0
Nevada	69.1	0	5.0	-40.3	0	-5.2	0
Total	20,857.0	0	0	0	0	0	0

Table 23. Estimated Change in Bushels of Corn and Soybeans Received by Elevator Locations From the Previous Solution in Thousands of Bushels, 1987

Elevator location	Base solution	Change from previous solution: Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
Albion	2,419.0	0	-1,614.3	-357.6	-126.1	-5.6	0
Clemons	160.3	0	295.9	-93.2	-5.7	-6.7	0
Ferguson	499.4	0	0	0	404.4	47.1	1.9
Gilman	66.5	0	5.7	0	-14.4	-2.3	0
Green Mountain	460.7	4.4	198.7	-47.9	-92.3	0	.9
Haverhill	271.9	0	29.2	-43.2	-56.2	-12.2	4.6
Laurel	245.7	0	20.8	-14.5	-40.1	-28.9	-11.1
Le Grand	99.7	0	105.9	-5.4	-63.5	-1.8	1.7
Liscomb	3,262.6	22.4	-1,598.1	-29.2	-108.8	4.5	0
Marshalltown	1,783.8	0	589.3	-116.6	-111.7	-15.1	3.3
Melbourne	1,265.6	0	153.6	-193.1	-245.7	-69.8	-28.8
Pickering	4,444.3	0	380.9	-332.0	-24.0	-3.9	4.9
St. Anthony	249.1	0	204.7	-67.3	-65.6	-0.5	0
State Center	147.4	0	132.0	-143.1	-45.2	-9.6	2.9
New Elevator	0	0	0	3,920.8	-19.7	121.5	17.9
Surrounding Marshall County							
Beaman	136.8	6.7	113.1	-20.1	63.9	-3.9	0
Colo	415.3	0	1,065.4	-1,158.4	-29.8	-7.4	0
Conrad	513.5	0	276.4	-50.9	-86.8	-5.4	0
Garwin	958.8	0	625.8	-143.0	251.3	0	1.8
Gladbrook	350.9	-33.5	0	0	52.2	0	0
Union	2,422.8	0	-2,054.7	-35.8	363.8	0	0
Nevada	6.0	0	1,069.7	-1,069.5	0	0	0
Total	20,180.1	0	0	0	0	0	0

Table 24. Estimated Changes in Bushels of Corn and Soybeans Received by Elevator Locations From the Previous Solution in Thousands of Bushels, 1988

		Change from previous solution					
Elevator location	Base solution	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
Albion	1,393.4	0	-1,000.6	-63.4	-119.4	-2.8	0
Clemons	207.2	0	130.7	-31.7	-64.9	11.3	0
Ferguson	658.4	0	0	-4.9	123.7	5.0	-2.5
Gilman	73.6	0	3.1	0	-9.5	0	0
Green Mountain	370.5	2.2	69.9	-17.8	-17.1	8.6	.6
Haverhill	579.4	0	76.7	-258.9	105.2	18.4	6.9
Laurel	257.7	0	9.2	-1.1	-18.1	-47.8	-8.9
Le Grand	1,235.0	0	112.5	-429.4	-16.8	-33.2	0
Liscomb	2,086.6	3.8	-1,612.3	-26.6	-135.3	0	0
Marshalltown	1,957.9	3.8	408.6	-293.4	110.1	-33.8	-0.3
Melbourne	2,064.9	0	166.4	-159.3	43.7	-79.6	-16.7
Pickering	2,146.0	0	157.9	-47.5	14.3	-23.4	-3.6
St. Anthony	287.1	0	245.7	-60.9	-39.6	-4.0	0
State Center	139.7	0	168.1	-154.1	-35.1	16.3	2.8
New Elevator	0	0	0	1,970.5	-45.4	176.5	25.0
Surrounding Marshall County							
Beaman	208.9	2.4	73.3	-9.5	-58.4	-1.3	0
Colo	476.6	0	257.4	-197.6	-41.4	10.1	-3.3
Conrad	69.3	0	161.7	-15.4	-14.8	-3.7	0
Garwin	2,908.7	0	579.7	-140.9	300.7	-8.8	0
Gladbrook	365.7	-12.2	0.3	-0.9	0.1	0	0
Union	267.6	0	3.7	-14.9	-79.9	-7.8	0
Nevada	70.9	0	0	-42.3	-2.1	0	0
Total	17,825.1	0	0	0	0	0	0

Figure 2. Estimated flow of corn from farms to elevators by farm tractor and one wagon, base solution, June, 1988.

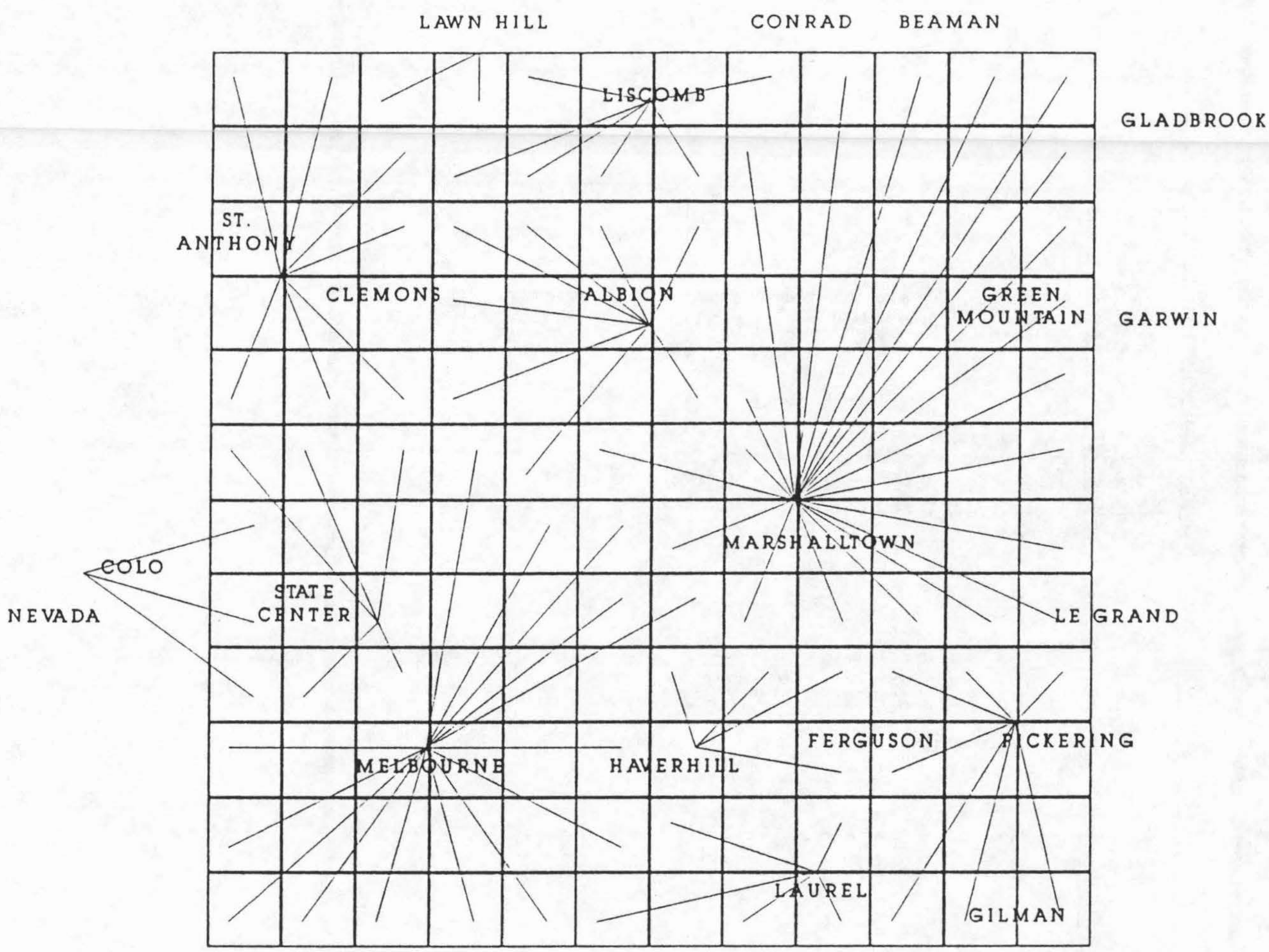


Figure 3. Estimated flow of corn from farms to elevators by farm tractor and one wagon, base solution, September 1988.

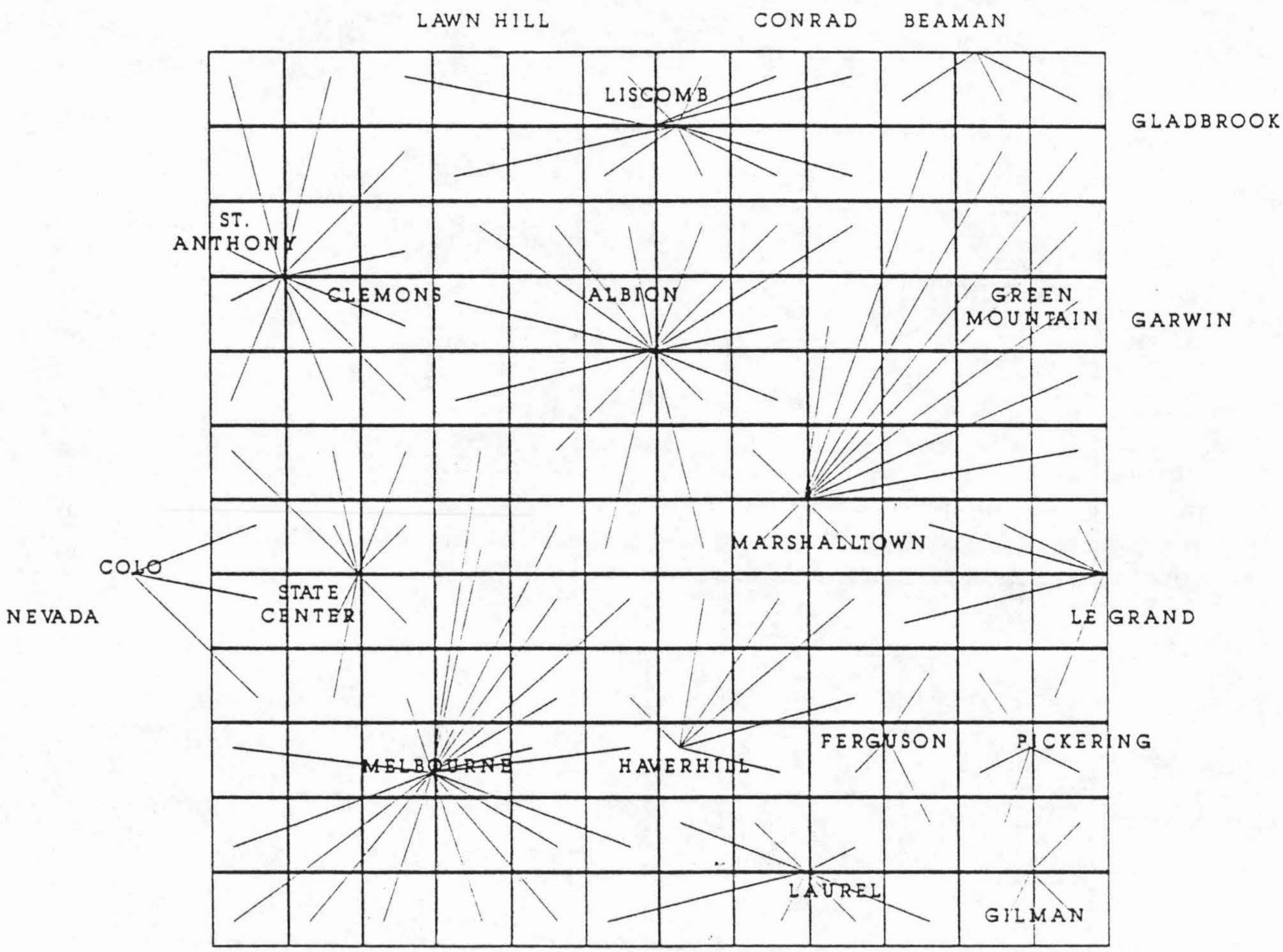
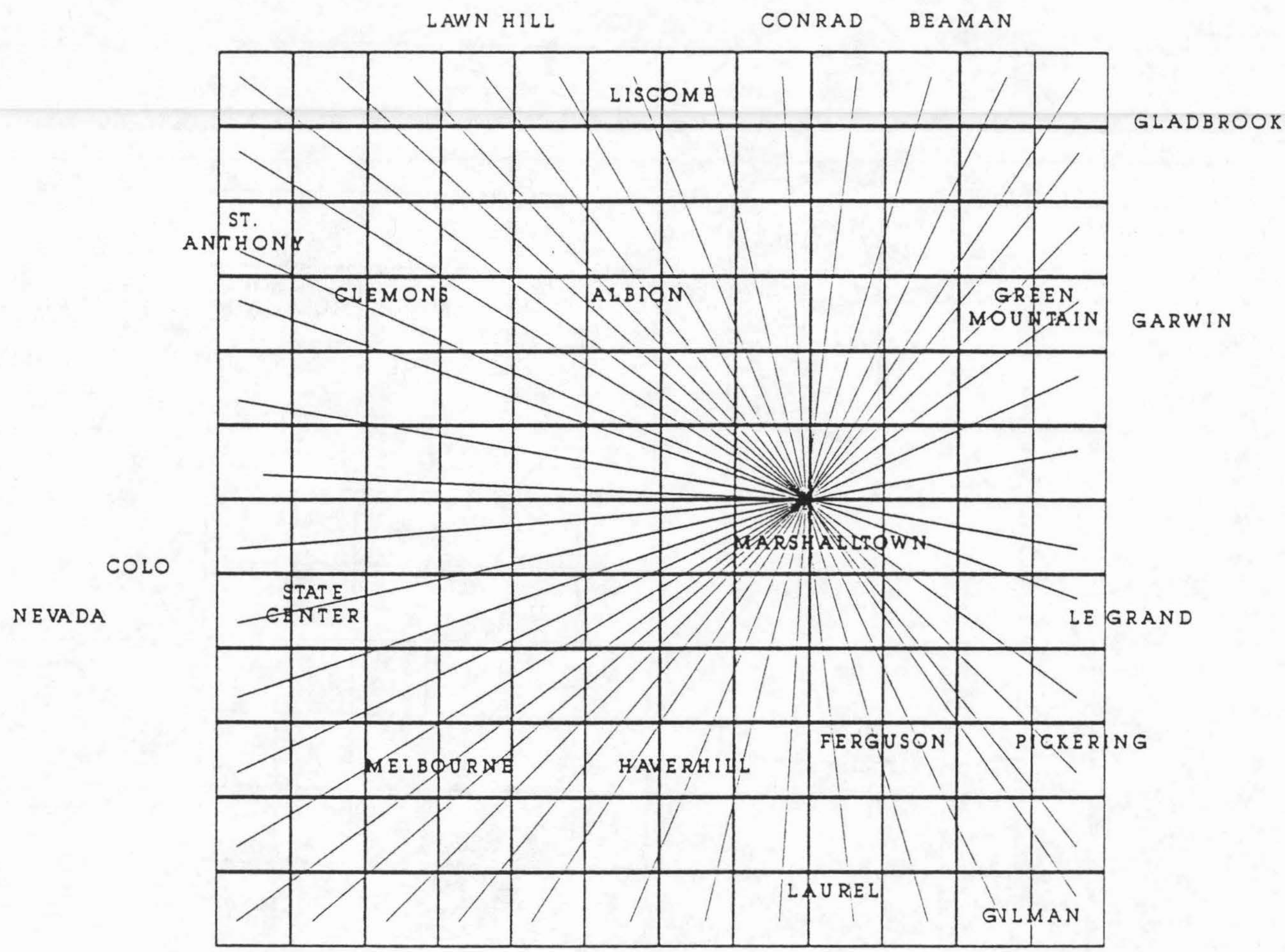


Figure 4. Estimated flow of corn from farms to elevators by semi tractor-trailer truck, base solution, June 1988.



elevator at Garwin. These changes illustrate the flexibility that larger trucks offer to farmers in response to changing grain bids.

(2) Abandonment of the Marshalltown-Green Mountain Branch Rail Line

Removal of the Green Mountain branch rail line had a minimal impact on grain flows. The elevator at Green Mountain shipped all of its grain by truck in all base solution years. The questionnaire data indicated that it actually shipped all of its grain by truck in 1986, 1987, and 1988. The only elevator location to lose grain receipts because of this abandonment was the elevator at Gladbrook. This elevator, located on the Green Mountain rail line northeast of Marshall County, lost between 9,800 and 33,500 bushels in the three years. These bushels were shifted to a number of other elevator locations. Thus, abandonment of this line had only a small impact on Marshall County grain flows in the computer model.

(3) Abandonment of the Marshalltown-Liscomb-Albion Branch Line

Abandonment of this line resulted in a major shift of corn and soybean receipts away from Liscomb and Albion. Receipts at these two locations declined by 3.0, 3.2, and 2.6 million bushels in 1986, 1987, and 1988, respectively. Also, the elevator at Union, located on this rail line north of Marshall County, lost substantial amounts of corn and soybean receipts--0.9 and 2.1 million bushels--in 1986 and 1987, respectively. Almost all other elevator locations gained receipts, because when a branch line is abandoned in the model, the grain shifts to the elevator with the next best net bid to the farmer. The elevator locations with the largest gains in grain receipts were at Marshalltown, Pickering, and Garwin. The elevator at Colo also had a large increase in grain receipts in 1987.

Figures 6 and 7 show the flow of corn from farms to elevators in a tractor-wagon combination for the months of June and September 1988 with the Liscomb-Albion line abandoned. As in the base solution, almost all elevators received corn by tractor-wagon. However, there were small shifts among elevators between the two months. For example, the elevator at Le Grand received little or no corn by tractor wagon in June but received substantial quantities during September. The elevator in Marshalltown received large quantities of corn by tractor-wagon in June but substantially less corn in September.

Figures 8 and 9 show the modeled flow of corn by tractor semi-trailer trucks in June and September 1988. The abandonment of the Albion-Liscomb line did not change the flow of corn by tractor semi-trailer trucks in June and September. The elevator at Marshalltown, which received all the tractor semi-trailer truck delivered corn in June in the base solution, continued to receive all the tractor semi-trailer truck delivered corn in June in the Albion-Liscomb abandonment

Figure 5. Estimated flow of corn from farms to elevators by semi tractor-trailer truck, base solution, September 1988.

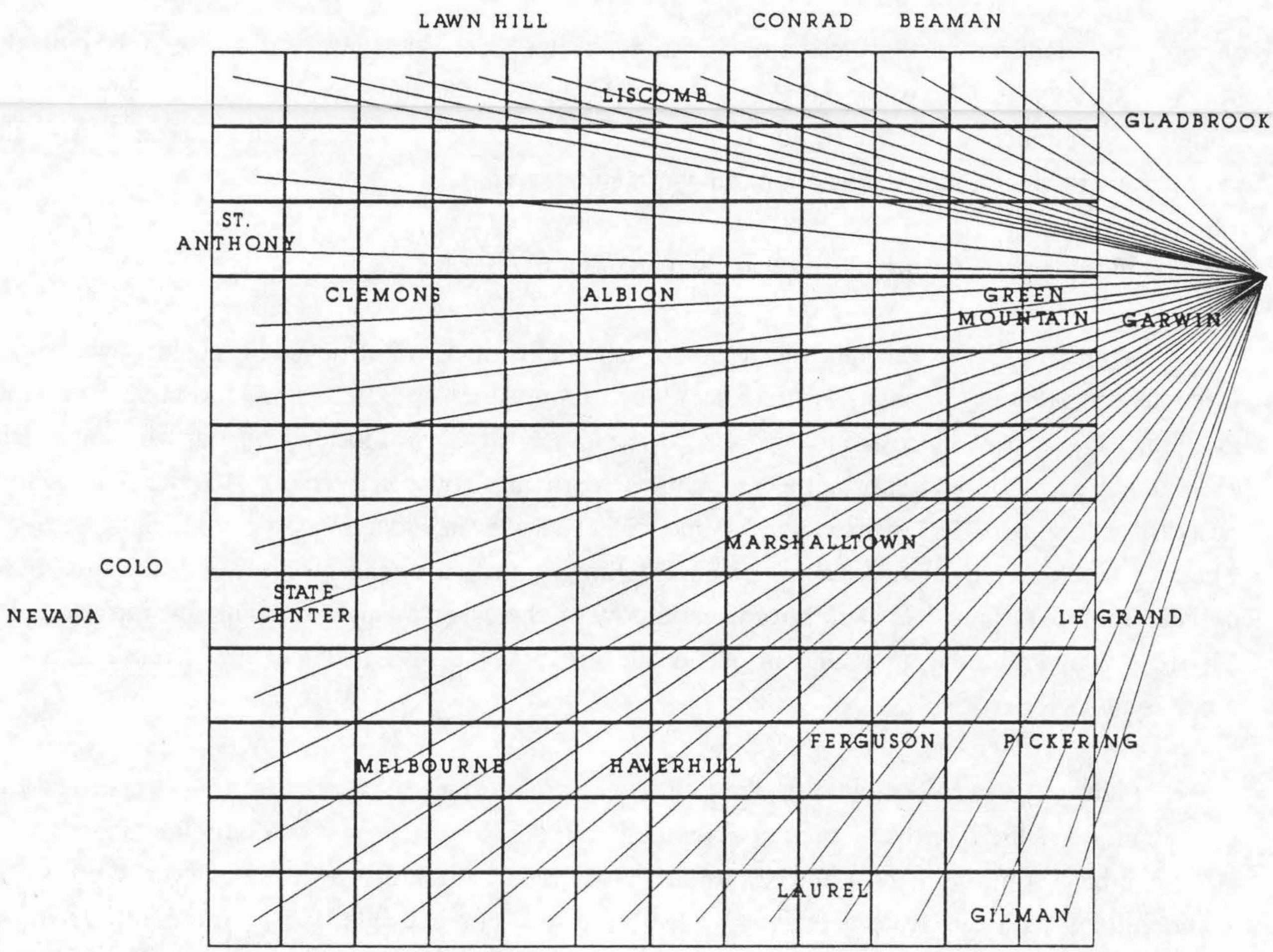


Figure 6. Estimated flow of corn from farms to elevators by farm tractor and one wagon, Albion-Liscomb abandonment solution, June 1988.

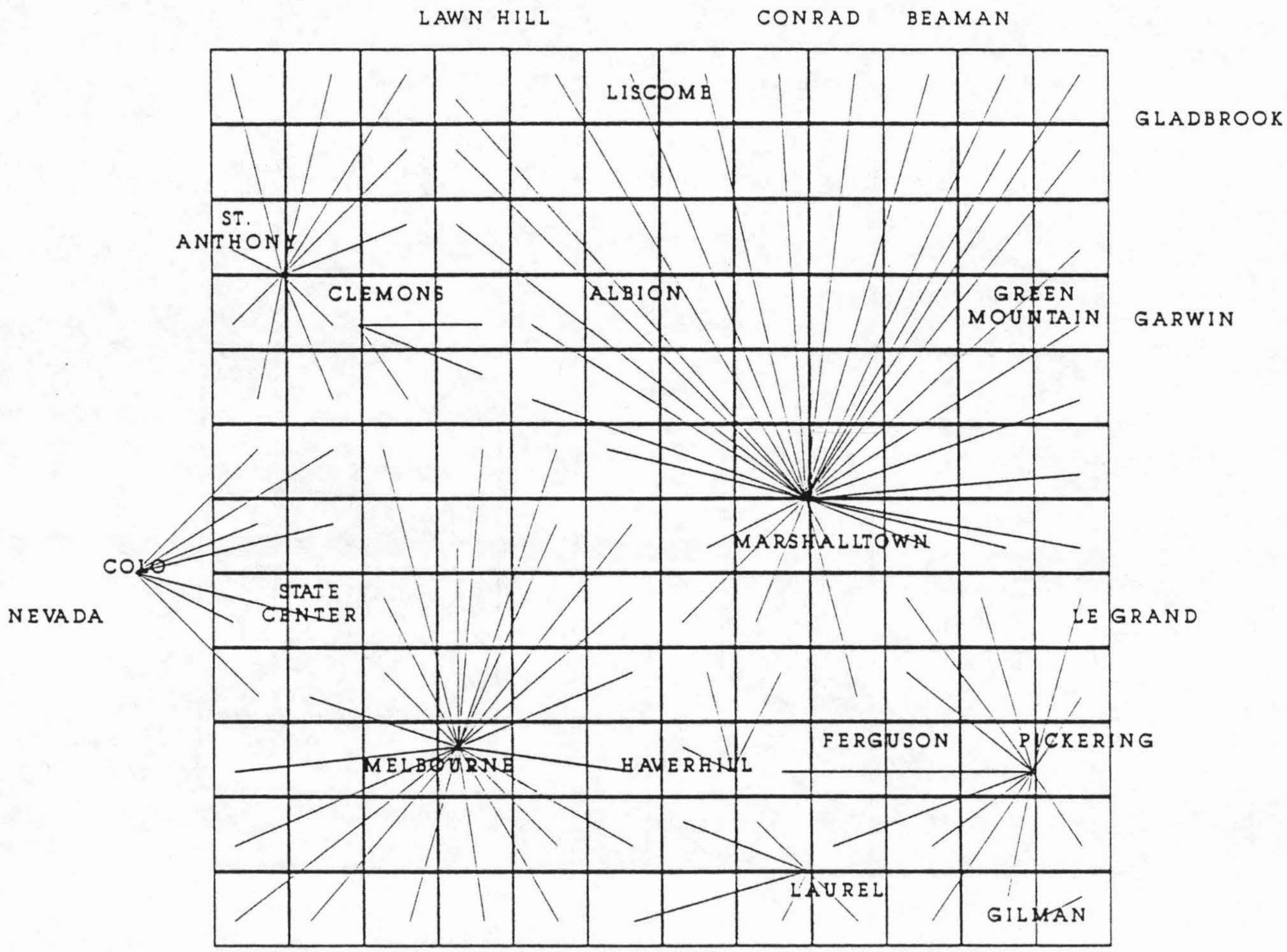


Figure 7. Estimated flow of corn from farms to elevators by farm tractor and one wagon, Albion-Liscomb abandonment solution, September 1988.

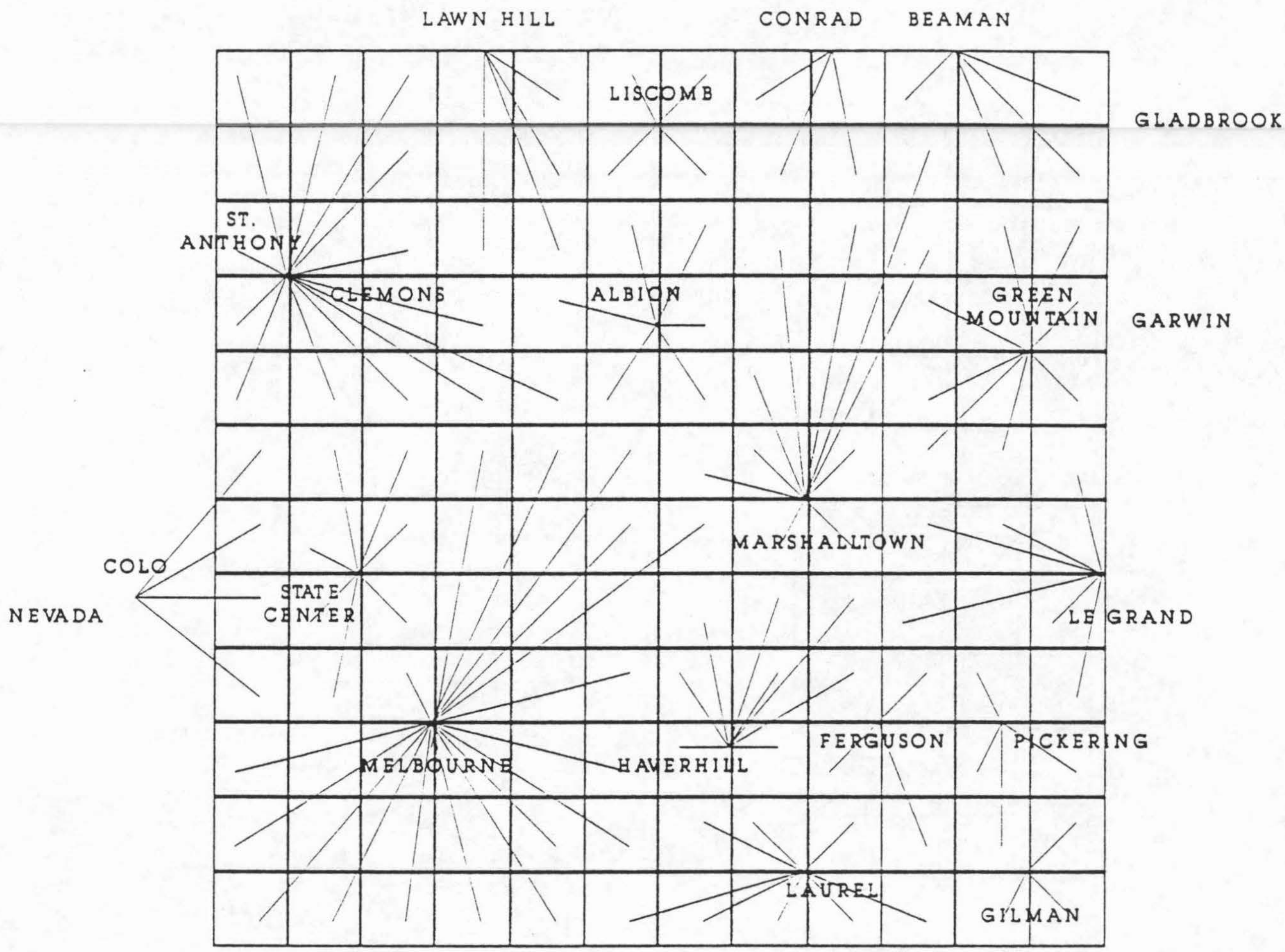


Figure 8. Estimated flow of corn from farms to elevators by semi tractor-trailer truck Albion-Liscomb abandonment solution, June 1988.

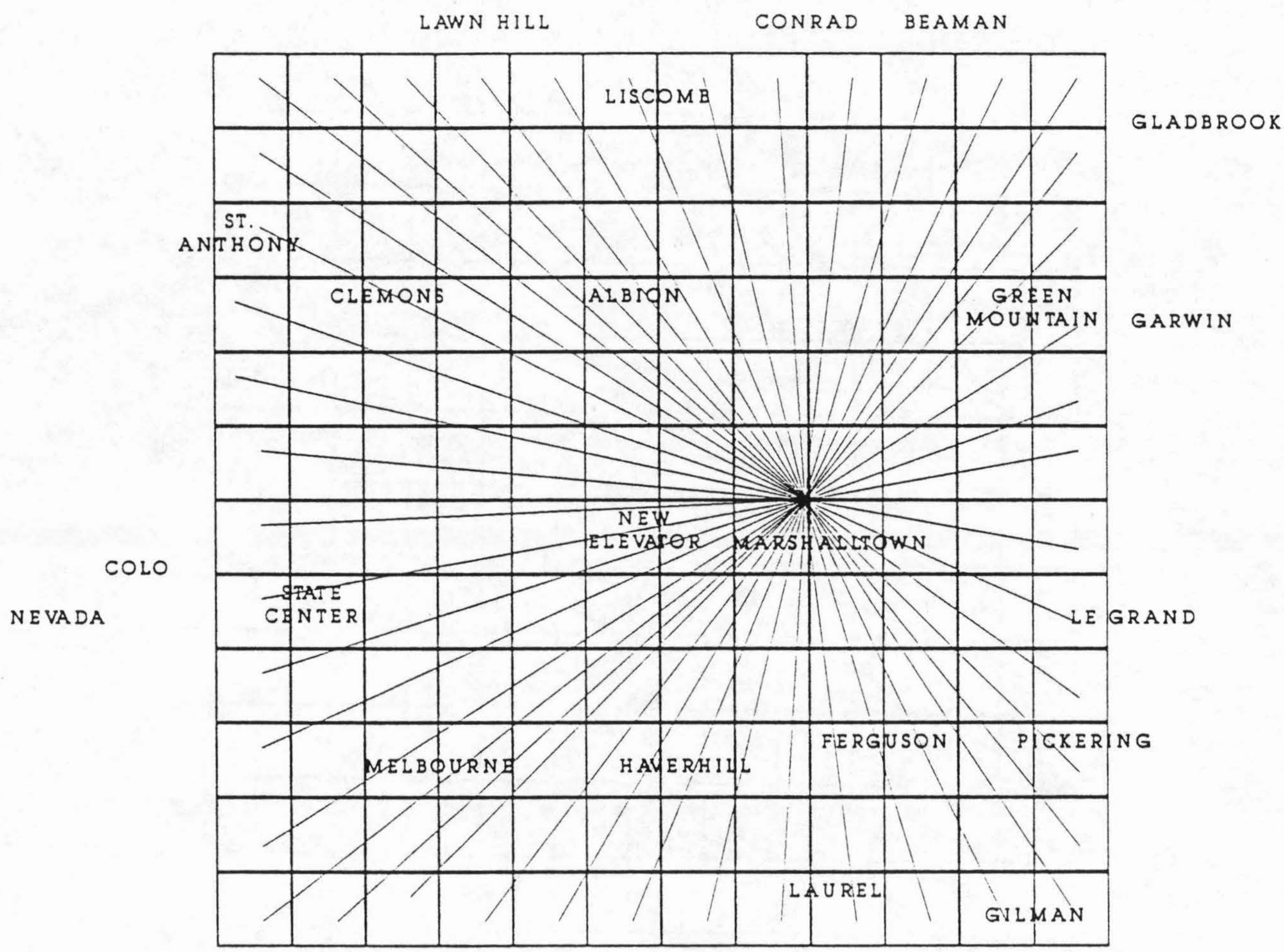
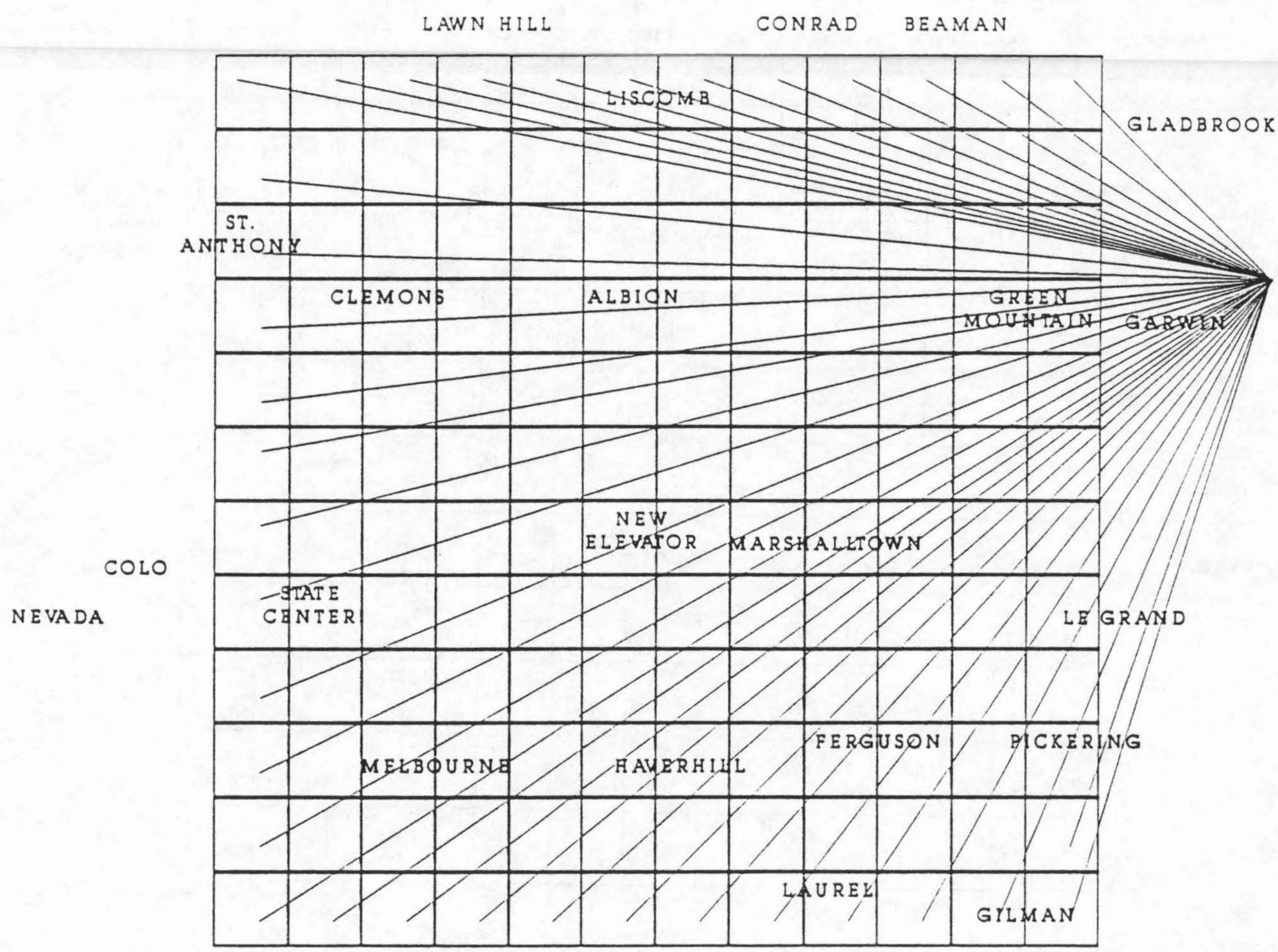


Figure 9. Estimated flow of corn from farms to elevators by semi tractor-trailer truck Albion-Liscomb abandonment solution, September 1988.



solution because the elevators at that location had the highest bid in June 1988. The same was true for Garwin in September 1988. Corn flows by tractor semi-trailer trucks did vary in other months.

(4) Construction of a New Grain Train Loading Elevator

A new train loading elevator constructed at the intersection of the CNW main line and country road S-75 was assigned grain prices equal to those paid by and received at the elevator at Nevada plus an additional one cent per bushel to reflect the shorter rail distance to Cedar Rapids and Clinton. This location became the elevator with the largest grain volume in this solution. The receipts at this elevator were 10.5, 19.4, and 11.1 percent of total receipts in 1986, 1987, and 1988, respectively. The new elevator's share was very high in 1987 because rail bids were relatively high for rail delivered corn at Clinton in that year. Almost all other elevator locations lost grain receipts to the new elevator. The largest losses occurred at the elevators at Garwin, Colo, and Marshalltown. Albion and Liscomb had relatively small losses because these two locations had already suffered large losses from the abandonment of the Liscomb-Albion rail line. The elevator locations that had gained receipts from the Albion-Liscomb branch line abandonment lost a major share of these gains to the new elevator.

Figures 10 and 11 show the flow of corn from farms to elevators by farm tractor-wagons for the new elevator solution. Most elevator locations continued to receive corn by farm tractor-wagons in both June and September 1988. However, the new elevator received corn from a large number of farms during June and September.

Figures 12 and 13 show the flow of corn from farms to elevators in tractor semi-trailer trucks. The elevator at Marshalltown received all the corn in June 1988. In September 1988, the elevator at Garwin had the high bid and, consequently, received all of the receipts by tractor semi-trailer trucks.

These data indicate that train loading elevators do not always have the highest bids, especially in areas where non-train loading elevators are located relatively close to truck markets. The data also indicate that the high bids to farmers, net of transport costs, shift among elevators by months.

(5) Upgrading County Road S-75 North of U.S. 30

This county road upgrading had a relatively minor impact on grain flows in all three years. This alternative shifted 0.9 million bushels of grain among elevators in 1986. In comparison, the new elevator shifted 2.2 million bushels, affecting almost all elevators. The elevators at Garwin,

Figure 10. Estimated flow of soybeans from farms to elevators by farm tractor and one wagon, new elevator solution, June 1988.

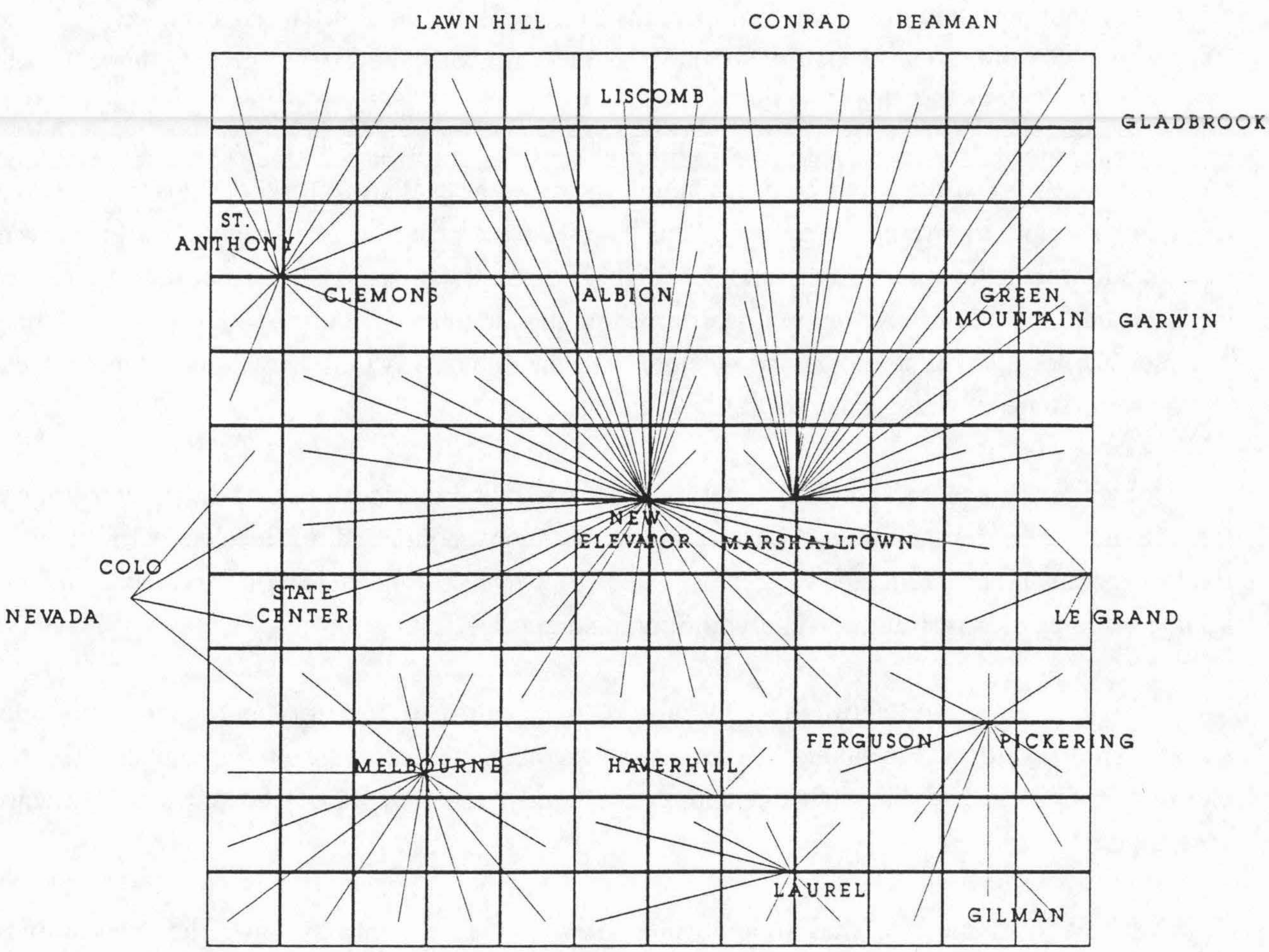


Figure 11. Estimated flow of soybeans from farms to elevators by farm tractor and one wagon, new elevator solution, June 1988.

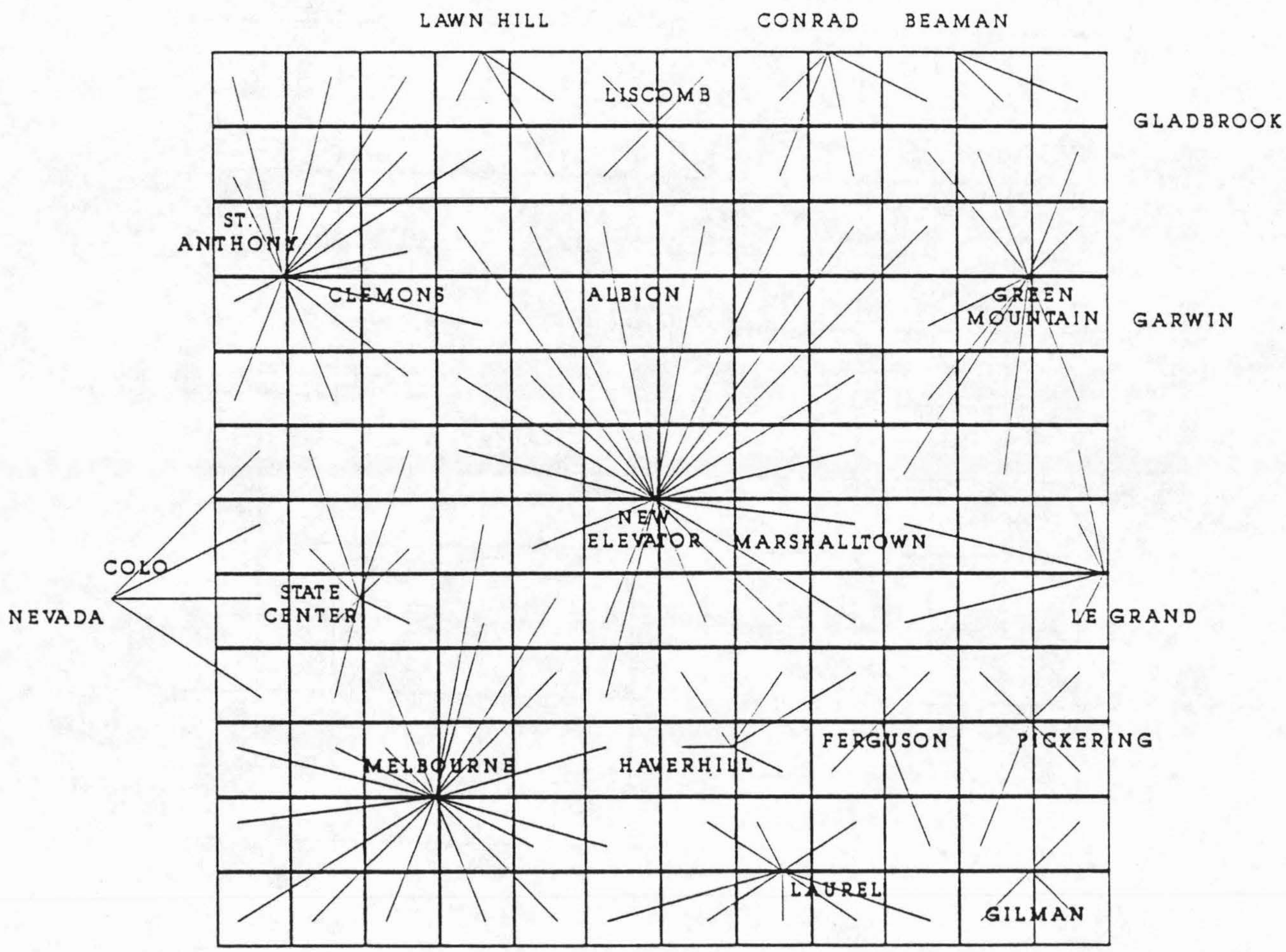


Figure 12. Estimated flow of corn from farms to elevators by semi tractor-trailer truck, new elevator solution, June, 1988.

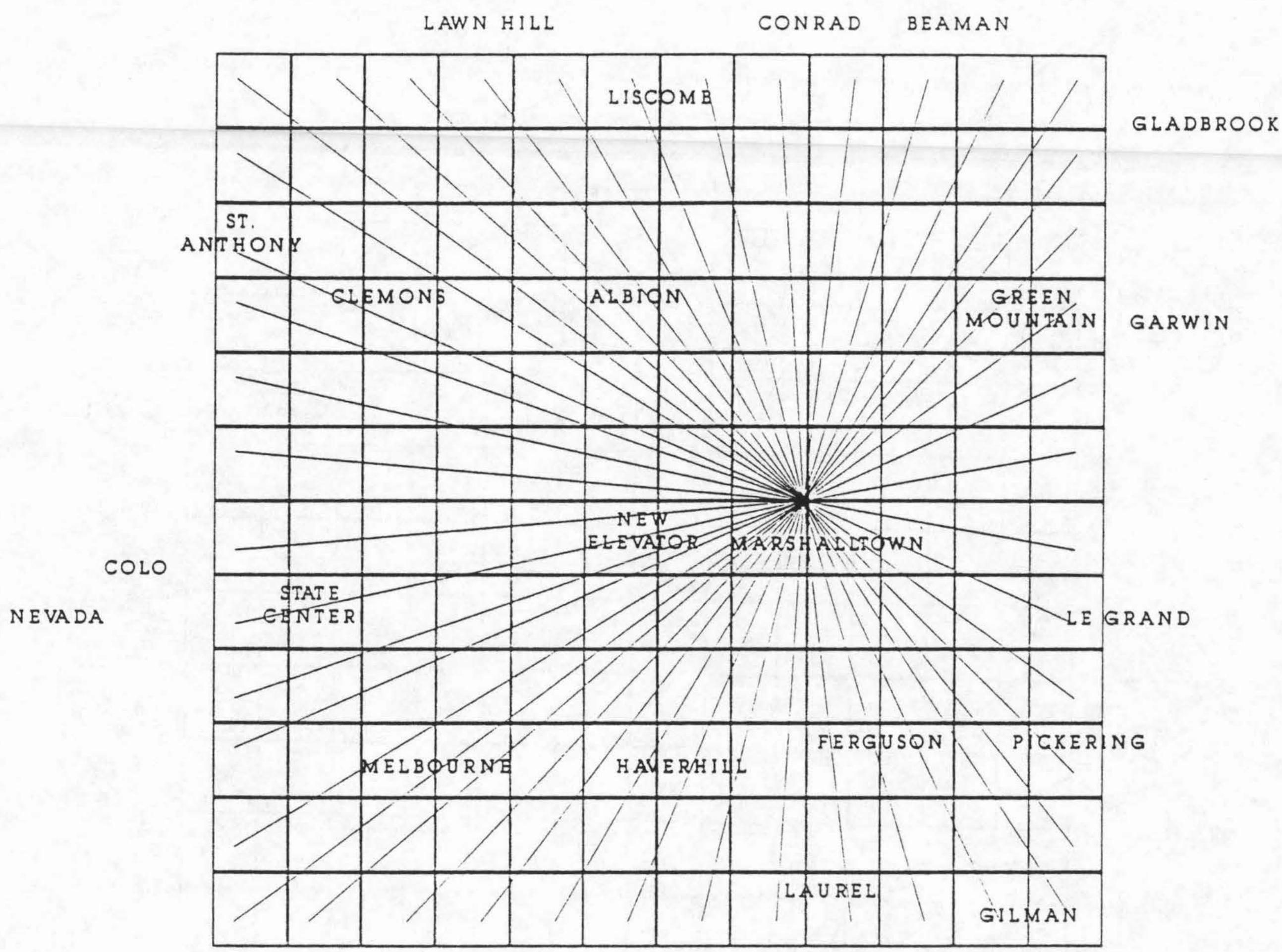
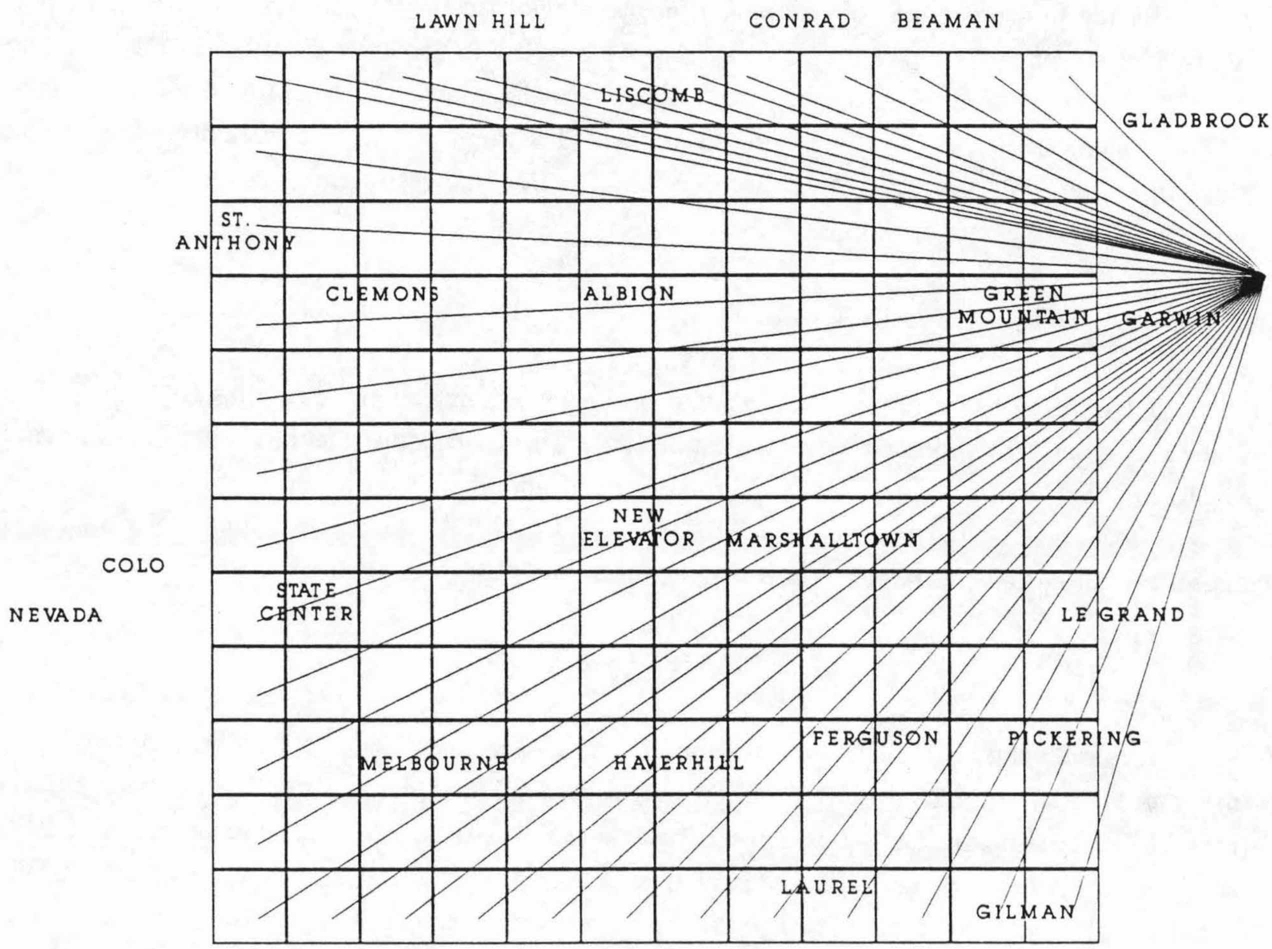


Figure 13. Estimated flow of corn from farms to elevators by semi tractor-trailer truck, new elevator solution, September, 1988.



Gladbrook, Marshalltown, and Ferguson had the largest increases in grain receipts from this upgrading. Most other locations had very small decreases. The reason for the relatively minor impact of upgrading S-75 north of U.S. 30 on grain flows was that this road segment was already paved and upgrading this route by adding shoulders, widening pavement, and adding a bypass around Albion reduced travel cost by only a small amount.

(6) Paving S-75 South of U.S. 30 to E-63

Paving this segment from a gravel surface to a rigid pavement shifted about 200,000 bushels of grain each year. The paving provided improved access to the new elevator on the mainline railroad and to the State Center and Haverhill elevator locations. This improved access resulted in sharp increases in receipts at these locations. The largest losses in receipts were at the Melbourne and Laurel locations in all three years. Smaller changes in grain receipts also occurred at several other elevator locations.

(7) Paving S-75 From E-63 to the County Line

Pavement of this section of S-75 had a very minor impact on grain flows. Only 24,000 bushels of grain shifted among elevator destinations. This road improvement resulted in improved access to the Haverhill, State Center, Marshalltown, and the new elevator location. The new elevator location had the largest increase in receipts in all three years while the Melbourne and Laurel elevators had the largest losses in receipts.

FARM GRAIN REVENUE

Table 25 shows the estimated revenue to farmers from the sale of corn and soybeans, net of variable transport costs for each solution. The base solution net revenues varied among years from $45 to $65 million largely as a result of changes in market prices for the grain. The 1988 base solution generated the largest estimated net revenue because grain prices were substantially higher in 1988 than in the other two years. There were also some changes in the quantity of corn and soybeans sold.

Changes in farm grain revenues among solutions within each year were caused by changes in bid prices and distances hauled as each solution caused grain to be shifted among elevators. The two abandonment solutions resulted in decreases in net farm grain revenue. However, the decrease in farm revenue from the Green Mountain line abandonment was negligible, ranging from $68 in 1986 to $120 in 1987. The reason for the very small decline in revenue was that only a small amount of grain was shipped on that rail line in the base solution.

Table 25. Estimated Change in Revenues to Farms, Net of Transport Costs From Corn and Soybeans by Solutions by Years

	1986	1987	1988
Base solution revenues	$45,774,245	$44,681,365	$64,505,222
Change from previous solution			
Green Mountain abandonment	-68	-120	-98
Albion-Liscomb abandonment	-146,877	-252,204	-114,102
New grain elevator	147,971	187,175	142,847
Upgrade S-75 north of U.S. 30	1,380	1,453	1,379
Pave S-75 between U.S. 30 and E-62	9,935	11,187	7,493
Pave S-75 between E-62 and county line	2,108	1,983	1,378

Abandonment of the Albion-Liscomb line resulted in a substantial reduction in net farm grain revenue ranging from $114,000 in 1988 to $252,000 in 1987. On an average per bushel basis, the reduction in net grain revenue from the Albion-Liscomb line abandonment ranged from about 0.7 cents per bushel in 1986 and 1988 to 1.3 cents per bushel in 1987. The reason for the larger per bushel revenue reduction in 1987 was that the differential between rail bids and truck bids to elevators were greater in 1987 than in 1986 and 1988, with rail bids being the higher of the two. Therefore, the loss of the Albion-Liscomb line eliminated these higher rail markets for much of the grain previously shipped on this line.

Construction of the new elevator west of Marshalltown more than restored the net farm grain revenue lost from the abandonment of the Albion-Liscomb line in 1986 and 1988 and restored 74 percent of the 1987 net revenue lost to farms from the Albion-Liscomb abandonment. On an average per bushel basis, the new elevator added 0.7 cents per bushel to all Marshall County grain sold in 1986, 0.8 cents per bushel in 1988, and 0.9 cents per bushel in 1987 to net farm grain income.

The upgrading of S-75 north of U.S. 30 added about $1,400 per year to net farm grain revenue in each of the three years. However, additional farm grain revenue from paving S-75 between U.S. 30 south to E-63 ranged from $7,500 in 1988 to over $11,000 to 1987. Paving S-75 south of E-63 added only between $1,378 to $2,108 per year to net farm grain revenue.

ELEVATOR-TO-MARKET FLOWS

Elevator Revenues

Table 26 shows the change in gross elevator revenues from the sale of corn and soybeans from the preceding solution. Total gross elevator revenues were defined as gross revenues to the elevators from the sale of the corn and soybeans net of transport costs to market. Total gross elevator revenues decreased slightly from the Green Mountain abandonment solution. The Albion-Liscomb solution resulted in a reduction in gross elevator revenue of $72,704 in 1986, $130,736 in 1987, and $93,200 in 1988. The construction of the new elevator restored more gross revenue in 1986 and 1988 than the elevators lost from the abandonment of the Albion-Liscomb branch line in those years. However, in 1987, the new elevator recovered only 81 percent of gross revenues lost by elevators in 1987. Moreover, not all of the elevators gained revenues. In fact, only the new elevator gained additional revenues while most of the elevators lost revenues.

Table 26. Estimated Change in Gross Elevator Revenues From the Sale of Corn and Soybeans From the Previous Solution by Year

	Years		
Solution	1986	1987	1988
Base	$48,671,088	$46,266,336	$62,497,632
Green Mountain abandonment	-2,032	-5,888	-2,488
Albion-Liscomb abandonment	-72,704	-130,736	-93,200
New Elevator	110,464	105,392	120,784
Upgrade S-75 North	1,712	1,392	856
Pave S-75 from U.S. 30 to E-63	1,136	832	72
Pave S-75 from E-63 to county line	800	111	48

The upgrading of S-75 north had only a small impact on elevator revenues, increasing gross revenues by approximately $900-$1,700 per year. The two pavings of S-75 south had even smaller impacts on elevator revenues. The pavings from U.S. 30 to E-63 increased elevator revenues from $1,136 in 1986 to $72 in 1988. The paving of S-75 from E-63 to the county line resulted in increased elevator revenues of $48 to $800.

Percent of Grain Transported From Elevators by Modes

Table 27 shows the percent of corn and soybeans shipped by truck and railroad from elevators-to-markets. Truck shipments dominated the movement of corn and soybean shipments out of Marshall County. The truck share ranged from 57.8 percent in the 1987 base solution to 73.9 and 80.4 percent in the 1986 and 1988 base solutions, respectively. The reason for the large increase in rail share in 1987 was the higher bids for grain at the rail markets relative to the truck markets at Cedar Rapids.

There was essentially no change in the truck and railroad shares of elevator shipments when the Green Mountain line was abandoned. However, the railroad share of total grain shipments declined sharply when the Albion-Liscomb line was abandoned. The new train loading facility restored the rail share of grain shipments to 3.6 percentage points above the base solution level in 1988 and to just 0.5 and 3.7 percentage points below the base solution levels in 1986 and 1987, respectively. The reason for the 1988 increase in rail shipments is explained in Table 28. There was a 3.6 percentage point increase in grain shipments to Clinton in 1988 over the 1977 shipments in the new elevator solution. Most of this increase in shipments to Clinton was by rail.

The upgradings of the three segments of county road S-75 resulted in a very small increase in the share of railroad grain shipments because the upgraded road provided improved access to elevators located on the main railroad line.

Table 27. Percent of Corn and Soybeans Shipped From Elevators by Truck and Rail by Solution and Year

	Years					
	1986		1987		1988	
Solution	Truck	Rail	Truck	Rail	Truck	Rail
Base	73.9	26.1	57.8	42.2	80.4	19.6
Green Mountain abandonment	74.2	25.8	58.7	41.3	81.0	19.0
Albion-Liscomb abandonment	86.1	13.9	73.4	26.6	89.0	11.0
New grain elevator	74.4	25.6	61.5	38.5	76.8	23.2
Upgrade S-75 North	74.2	25.8	61.3	38.7	76.7	23.3
Pave S-75 from U.S.-30 to E-63	74.2	25.8	61.2	38.8	76.2	23.8
Pave S-75 from E-63 to county line	74.1	25.9	61.2	38.8	76.2	23.8

Destinations of Elevator Grain Shipments

Table 28 shows the 1986, 1987, and 1988 destinations of the corn and soybean shipments from the Marshall County and surrounding elevators. The dominate markets in all three years were Cedar Rapids, Des Moines, and Clinton. The Cedar Rapids and Des Moines markets gained market shares as the branch lines were abandoned because these were the two dominant truck markets. The Clinton market lost shares with rail abandonment; however, it regained part of the lost market share with the construction of the new elevator because the new elevator shipped a large share of its grain by rail. The Clinton market also had small gains in market shares as S-75 was upgraded or paved, which improved access to rail shipping elevators.

OTHER AGRICULTURAL TRAFFIC

Fertilizer

Table 29 shows the change in the cost of delivering fertilizer to local dealers. The assumption was made that any fertilizer received by rail at locations on rail lines abandoned in this study would be delivered by rail to Marshalltown and then trucked to the dealers. The elevator

Table 28. Percent of Corn and Soybeans Sold to Markets by Elevators and Year

		Markets						
Year	Solution	Cedar Rapids	Davenport	Des Moines	Muscatine	Clinton	IowaFalls	Total
1986	Base	57.4	1.8	13.0	0.4	26.7	0.7	100
	Green Mountain abandonment	57.7	1.8	13.0	0.4	26.4	0.7	100
	Albion-Liscomb abandonment	66.9	2.0	15.4	0.5	14.8	0.5	100
	New elevator	57.6	1.9	13.3	0.5	26.2	0.5	100
	Upgrade S-75 North	57.4	1.9	13.2	0.5	26.4	0.5	100
	Pave S-75 from U.S. 30 to E-63	57.4	1.9	13.2	0.5	26.5	0.5	100
	Pave S-75 from E-63 to county line	57.3	1.9	13.2	0.5	26.6	0.5	100
1987	Base	37.1	3.2	16.3	0	41.8	1.6	100
	Green Mountain abandonment	38.0	3.2	16.3	0	40.9	1.6	100
	Albion-Liscomb abandonment	50.9	4.6	18.6	0	24.6	1.3	100
	New elevator	44.3	3.3	21.0	0	30.2	1.3	100
	Upgrade S-75 North	44.2	3.3	21.0	0	30.2	1.3	100
	Pave S-75 from U.S. 30 to E-63	44.2	3.2	21.0	0	30.3	1.3	100
	Pave S-75 from E-63 to county line	44.2	3.2	21.0	0	30.3	1.3	100
1988	Base	50.5	0.8	27.3	0.3	19.8	1.2	100
	Green Mountain abandonment	51.2	0.8	27.3	0.3	19.2	1.2	100
	Albion-Liscomb abandonment	53.6	0.8	32.8	0.4	11.1	1.2	100
	New elevator	46.7	0.8	36.0	0.3	15.1	1.1	100
	Upgrade S-75 North	46.6	0.8	36.1	0.3	15.2	1.1	100
	Pave S-75 from U.S. 30 to E-63	46.3	0.8	36.3	0.3	15.2	1.1	100
	Pave S-75 from E-63 to county line	46.2	0.8	36.4	0.3	15.2	1.1	100

questionnaires indicated that no fertilizer was received by rail on the Green Mountain line but fertilizer dealers located on the Albion-Liscomb line received some fertilizer by rail in 1987 and 1988.

Table 29. Estimated Change in Variable Cost of Transporting Fertilizer to Dealers From the Previous Solution by Year

Solution	Year 1986	1987	1988
Green Mountain abandonment	$0	$ 0	$ 0
Albion-Liscomb abandonment	0	886	415
New grain elevator	0	0	0
Upgrade S-75 North	0	-44	-20
Pave S-75 from U.S. 30 to E-63	0	0	0
Pave S-75 from E-63 to county line	0	0	0

The abandonment of the Albion-Liscomb line had no impact on deliveries to fertilizer dealers in 1986 because these locations received no fertilizer by rail in 1986. However, the abandonment did increase delivery costs in 1987 and 1988 by $886 and $415, respectively. The upgrading of S-75 north lowered delivery costs by less than $50 per year.

Table 30 shows the impacts of the seven computer solutions on liquid and dry fertilizer deliveries to farms. All fertilizer deliveries to farms were by truck. Therefore, the rail abandonment solutions had no impact on fertilizer deliveries to farms. The only solutions affecting fertilizer deliveries to farms were the two pavings of S-75 south of U.S. 30. Fertilizer delivery costs to farms declined in all years in these two solutions. However, the cost reductions were negligible.

Table 30. Estimated Change in Variable Transport Cost From the Previous Solution for Deliveries of Fertilizer to Farms by Year

	Year					
	1986		1987		1988	
Solution	Dry	Liquid	Dry	Liquid	Dry	Liquid
Green Mountain abandonment	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
Albion-Liscomb abandonment	0	0	0	0	0	0
New grain elevator	0	0	0	0	0	0
Upgrade S-75 North	-1	-1	-1	-1	-1	-1
Pave S-75 from U.S. 30 to E-63	-12	-9	-11	-6	-10	-8
Pave S-75 from E-63 to county line	-6	-5	-5	-3	-4	-4

Other Farm Commodity Traffic

Data from the railroad indicated that, other than grain and fertilizer, no farm commodities moved on Marshall County branch rail lines during 1986, 1987, and 1988. Therefore, the abandonment of the two branch rail lines and the construction of the new elevator had no impact on the transport of these commodities.

Table 31 shows the estimated miles of truck traffic for livestock, seed, and other farm commodity traffic in the base solution and the three road upgrading solutions. Hogs and cattle accounted for the largest number of truck miles for these other agricultural products. Total truck miles for hogs ranged from 27,723 miles in 1986 to almost 38,000 miles in 1988. Total truck miles for cattle ranged from 24,281 miles in 1987 to over 28,000 miles in 1988.

Table 31. Estimated Change in Transport Miles for Other Farm Commodities From the Previous Solution by Type of Commodity and Year

			Change from previous solution		
Year	Type of commodity	Base solution	Upgrading S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county
1986	Hogs	27,723	0	-24	-8
	Cattle	28,372	0	16	-50
	Milk	11,886	-68	10	-72
	Sheep	10,622	2	-14	-1,664
	Seed	105	0	0	0
	Other	52	0	0	0
	Total	78,760	-66	-12	-1,794
1987	Hogs	30,779	0	-30	-8
	Cattle	24,281	0	12	-48
	Milk	10,807	-69	10	-63
	Sheep	10,609	2	-14	-1,664
	Seed	105	0	0	0
	Other	52	0	0	0
	Total	76,633	-67	-22	-1,783
1988	Hogs	37,904	0	-37	-10
	Cattle	28,372	0	16	-50
	Milk	10,073	-68	5	-54
	Sheep	14,510	3	-18	-2,394
	Seed	105	0	0	0
	Other	52	0	0	0
	Total	91,016	-65	-34	-2,508

The upgrading of S-75 north had only a small impact on the truck miles for other farm products because this road had already been paved. Paving S-75 south to E-63 also resulted in only small reductions in truck miles for all of these commodities. Paving S-75 from E-63 to the county line had only a minor impact on truck miles, the largest reduction being 2,394 miles for sheep in 1988.

Table 32 shows the change in transport cost for these products for the base and the three road upgrading solutions. All three road solutions reduced trucking costs but the savings were small. Paving S-75 from U.S. 30 to E-63 and upgrading S-75 north each resulted in an average savings of less than $100 per year. Paving S-75 from E-63 to the county line resulted in transport cost savings of $400-$500 per year.

Table 32. Estimated Change in Variable Transport Costs for Other Farm Commodities From the Previous Solution by Types of Commodity and Year

			Change from previous solution		
Year	Type of commodity	Base solution	Upgrading S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
1986	Hogs	$15,053	$-12	$-57	$-31
	Cattle	15,269	-26	-13	-15
	Milk	6,947	-58	0	-68
	Sheep	2,533	-2	-4	-301
	Seed	55	-1	0	0
	Other	27	0	0	0
	Total	$39,884	$-99	$-74	$-415
1987	Hogs	$16,709	$-13	$-59	$-31
	Cattle	13,061	-22	-9	-13
	Milk	6,321	-57	0	-59
	Sheep	2,531	-2	-5	-301
	Seed	55	-1	0	0
	Other	27	0	0	0
	Total	$38,704	$-95	$-73	$-404
1988	Hogs	$20,582	$-13	$-78	$ -41
	Cattle	15,269	-26	-13	-15
	Milk	5,891	-56	0	-49
	Sheep	3,468	-2	-5	-411
	Seed	55	-1	0	0
	Other	27	0	0	0
	Total	$45,292	$-98	$-96	$-516

NON-FARM TRAVEL

Table 33 shows the estimated miles of non-farm travel in the base and three road upgrading solutions. There was a total of 47.4 million miles of non-farm travel in the base solution. Over 73 percent of total miles driven was for shopping, 5.6 percent was for guests of various types, and 11.7 percent for commuting-to-work. Upgrading S-75 had no impact on miles traveled because automobile and single axle truck costs vary little between rigid and flexible road surfaces. Paving S-75 between U.S. 30 and E-63 reduced travel by slightly over 12,000 miles or 0.03 percent of total base solution miles. Paving S-75 from E-63 to the county line reduced non-farm travel by 4,228 miles or 0.008 percent of total base solution. The largest reduction in miles traveled was for shopping.

Table 33. Estimated Change in Miles for Non-Farm Travel From the Base Solution by Type of Travel

Type of trip	Base solution	Change from previous solution: Upgrading S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
Shopping	34,791,280	0	-14,016	-4,160
Guests	2,662,709	0	895	0
Household delivery	945,200	0	78	86
Commuting	5,512,365	0	0	0
Salespersons	474,873	0	159	0
Hired help	979,773	0	181	0
Other	1,987,969	0	299	-154
Total	47,354,169	0	-12,404	-4,228

Table 34 shows the variable, non-farm travel costs for the base solution and the change in travel cost for each other solution. Total variable cost in the base solution was estimated to be almost $9.6 million. Shopping accounted for 62.5 percent of the total variable cost.

Table 34. Estimated Change in Variable Transport Costs for Non-Farm Travel From the Base Solution by Type of Travel

Type of trip	Base solution	Change from previous solution: Upgrading S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
Shopping	$6,013,060	$-10,643	$-8,592	$-2,116
Guests	599,852	-406	-223	0
Household delivery	467,032	-707	-341	-136
Commuting	1,266,195	-1,580	0	-999
Salespersons	106,963	-73	-39	0
Hired help	219,517	-286	-182	0
Other	900,812	-1,009	-699	-253
Total	$9,573,431	$-14,704	$-10,076	$-3,504

Upgrading S-75 north reduced non-farm travel costs by only $14,704--a reduction of 0.2 percent. Paving S-75 from U.S. 30 to E-63 reduced variable travel cost by $10,076--a 0.1 percent reduction in total base solution variable cost. Paving the section of S-75 from E-63 to the country line reduced variable travel costs by only $3,504--a reduction of only 0.04 percent.

TOTAL MILES DRIVEN

Table 35 shows the total miles driven by vehicle type for the base solution and the change

Table 35. Estimated Change in Miles Driven From the Previous Solution by Vehicle Type and Year

			Change from previous solution					
Year	Vehicle type	Base solution	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
1986								
	Automobile	44,270,337	0	0	0	45	-12,790	-5,823
	Single-axle	2,805,797	0	7,383	-208	98	209	-1,127
	Tandem-axle	331,156	0	12,649	-33,036	-712	-423	-2,650
	Semi	2,856,608	7,895	487,845	-382,239	-2,267	-3,907	-15,491
	Farm-tractor-wagons	221,900	54	2,686	-2,629	271	322	-475
	Total	50,485,798	7,949	510,563	-418,112	-2,565	-16,589	-25,566
1987								
	Automobile	44,270,324	0	0	0	45	-12,790	-5,823
	Single-axle	2,791,229	0	14,957	-13,864	-346	49	-320
	Tandem-axle	283,162	0	4,096	-15,476	-878	-769	-309
	Semi	2,369,998	24,459	595,865	-549,581	-3,400	-6,488	-15,564
	Farm-tractor-wagons	216,115	387	-1,720	-3,138	328	82	73
	Total	49,930,828	24,846	613,198	-580,059	-4,251	-19,916	-21,943
1988								
	Automobile	44,274,225	0	0	0	46	-12,794	-6,553
	Single-axle	2,797,771	0	5,648	-5,070	65	147	-351
	Tandem-axle	229,628	0	24,701	-21,092	-236	-723	-392
	Semi	3,329,668	14,944	577,411	-525,560	-3,883	-14,239	-14,632
	Farm-tractor-wagons	188,245	-194	5,909	-5,779	152	210	67
	Total	50,819,537	14,750	613,669	-557,501	-3,856	-27,399	-21,861

in miles driven in each solution. Total rural travel miles ranged from 49.9 million miles in 1987 to 50.8 million miles in 1988. Over 88 percent of all travel miles was by automobile.

The Green Mountain branch line abandonment increased total miles driven by 0.05 percent in 1987 and even less in 1986 and 1988. Almost all of the increase was in tractor semi-trailer trucks. The Albion-Liscomb branch line abandonment resulted in a much greater increase in miles driven, ranging from an increase of 1.0 percent in 1986 to 1.2 percent in 1987. Over 94 percent of the net increase in miles driven each year was by tractor semi-trailer trucks, mostly for hauling grain from elevators to markets. The increase in tractor semi-trailer truck miles driven in 1987 was larger than in 1986 and 1988 because 1987 bid prices at the rail markets in Clinton were relatively higher than at the truck markets in Cedar Rapids and Des Moines. Thus, when the train loading elevators at Albion-Liscomb lost rail service, the grain was rerouted to other elevators, some of which had no rail service. Hence, more of the diverted grain was trucked to market.

Table 36 shows the miles of tractor semi-trailer truck miles for agricultural purposes. In the base solution, elevator-to-market truck miles were over 90 percent of total semi-trailer truck miles in each of the three years. Farm-to-elevator tractor semi-trailer truck miles ranged from 5.0 to 7.2 percent. In the Albion-Liscomb abandonment, the elevator-to-market share of additional tractor semi-trailer miles ranged from 98 to 99.7 percent of the change in total agricultural tractor semi-trailer miles. The remainder was farm-to-elevator miles. Thus, most of the additional tractor semi-trailer miles for agricultural purposes were for grain shipment from elevator-to-market trips.

The new grain elevator reduced total miles driven by about 400,000 miles in 1986 and over 500,000 miles in 1987 and 1988. The new elevator shipped most of its grain by rail, reducing elevator-to-market truck miles driven. The new elevator also reduced farm-to-elevator miles by providing higher bid prices and reducing the number of miles farmers hauled grain to elevators.

Upgrading S-75 north of U.S. 30 had only a minimal impact on total miles driven. Paving S-75 south to E-63 and from E-63 to the county line also resulted in relatively small decreases in miles driven by all vehicle types. Paving S-75 south to E-63 reduced total base solution miles by 0.03 percent in 1986, 0.04 percent in 1987, and 0.05 percent in 1988. Paving S-75 from E-63 south to the county line reduced total base solution miles driven by 0.05 percent in 1986 and 0.04 percent in 1987 and 1988.

SAFETY COSTS

Table 37 shows the estimated change in safety costs from the previous solution. The Green Mountain and Albion-Liscomb rail line abandonment solutions each increased safety costs on both county and state roads in Marshall County. Almost all of these additional safety costs came from

Table 36. Estimated Change in Agricultural Tractor Semi-Trailer Truck Miles by Type of Travel 1986, 1987, and 1988

			Change from previous solution					
Year	Purpose of trip	Base solution	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
1986	Grain							
	farm-to-elevator	179,333	0	11,229	-3	31	-264	-341
	elevator-to-market	2,621,180	7,895	476,616	-382,236	-2,298	-3,635	-15,092
	Livestock	56,095	0	0	0	0	-8	-58
	Total	2,856,608	7,895	487,845	-382,239	-2,267	-3,907	-15,491
1987	Grain							
	farm-to-elevator	171,923	1	8,404	-13,353	30	-248	-54
	elevator-to-market	2,142,995	24,458	585,790	-536,228	-3,430	-6,222	-15,454
	Livestock	55,080	0	0	0	0	-18	-56
	Total	2,369,998	24,459	594,194	-549,581	-3,400	-6,488	-15,564
1988	Grain							
	farm-to-elevator	166,595	0	1,762	-3,282	0	-174	-143
	elevator-to-market	3,096,797	14,944	574,867	-522,278	-3,883	-14,044	-14,429
	Livestock	66,276	0	0	0	0	-21	-60
	Total	3,329,668	14,944	576,629	-525,560	-3,883	-14,239	-14,632

Table 37. Estimated Change in Vehicle Safety Costs From the Previous Solution by Type of Road and Year

		Change from previous solution					
Year	Type of road	Green Mountain abandonment	Albion-Liscomb abandonment	Upgrade New grain elevator	Pave S-75 North of U.S. 30	Pave S-75 South to E-63	S-75 to county line
1986	State	$ 0	$16,205	$ -9,251	$66,305	$ 4,156	$ 3,243
	County	332	6,283	-8,982	-66,575	-4,639	-6,122
	Total	$ 332	$22,488	$-18,233	$ -270	$ -483	$-2,879
1987	State	$ 0	$16,434	$-14,419	$65,712	$ 4,176	$ 3,845
	County	1,044	10,379	-11,079	-66,000	-4,457	-4,423
	Total	$1,044	$26,813	$-25,498	$ -288	$ -281	$- 578
1988	State	$ 0	$23,297	$-15,866	$63,664	$ 3,790	$ 3,932
	County	622	4,113	-8,641	-63,989	-4,442	-4,512
	Total	$ 622	$27,410	$-24,507	$ -325	$ -652	$ -580

additional travel from tractor semi-trailer grain trucks. The Green Mountain abandonment created only very small increases in safety costs--$1,000 or less--in each of the three years. The Albion-Liscomb abandonment resulted in increased safety costs ranging from $22,488 in 1986 to $27,410 in 1988. The increased safety costs between 1986 and 1987 occurred on county roads because of the increased travel from farms-to-elevators as farmers shifted to elevators with higher net prices. Safety costs remained high in 1988 because elevators hauled more grain by truck since truck markets had relatively higher grain bids.

Much of the grain which had shifted to truck in the Albion-Liscomb abandonment returned to the railroad when the new elevator was established. Farmers hauled large quantities of grain to the new elevator, which in turn, shipped most of its grain by rail. Consequently, the new elevator reduced vehicle safety costs in all three years on both county and state roads.

Upgrading S-75 north reduced safety costs in all three years. The upgraded highway resulted in additional traffic on state roads, but the increase was offset by a larger reduction in county road safety costs.

Paving S-75 south to E-63 resulted in an increase in automobile traffic on state roads and hence an increase in safety costs on state roads. However, this paving decreased automobile traffic on county roads with the net result being a reduction in total safety costs for all three years ranging from $281 in 1987 to $652 in 1988.

Paving S-75 from E-63 south to the county line also resulted in increased miles driven and safety costs on state roads. However, a larger decrease in miles driven on county roads caused a decrease in safety costs on county roads. The net reduction in safety costs was $2,879 in 1986, with smaller amounts in 1987 and 1988.

ROAD MAINTENANCE COSTS

Table 38 shows the changes in variable road maintenance costs from each previous solution. Road maintenance costs increase slightly with the Green Mountain rail line abandonment. However, the Albion-Liscomb line abandonment shifted large quantities of grain from rail to trucks, which increased variable road maintenance costs substantially. Road maintenance costs then declined in the new elevator solution because the new elevator, located on the main rail line, increased the amount of railroad grain shipments and decreased truck shipments from elevators-to-markets.

Upgrading S-75 north substantially reduced county road maintenance costs. However, paving S-75 from U.S. 30 to E-63, and paving S-75 from E-63 to the county line had only minor

Table 38. Estimated Change in Road Maintenance Costs From the Previous Solution by Road Type and Solution

		Change from previous solution					
Year	Type of road	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
1986	State	$ 0	$ 927	$ -536	$ 356	$ 2	$ 35
	County	522	10,732	-12,414	-9,003	30	-172
	Total	$ 522	$11,659	$-12,950	$-8,647	$ 32	$-137
1987	State	$ 0	$ 927	$ -818	$ 309	$ 3	$ 45
	County	1,618	18,927	-14,557	-7,974	-28	-184
	Total	$1,618	$19,854	$-15,375	$-7,665	$-25	$-139
1988	State	$ 0	$ 1,332	$ -911	$ 200	$ -18	$ 49
	County	987	5,746	11,566	-5,329	-208	-68
	Total	$ 987	$ 7,078	$-12,477	$ 5,129	$ 226	$ -19

impacts on variable road maintenance costs.

MOTOR FUEL TAX REVENUES

Table 39 shows the estimated fuel taxes paid by registered vehicles in each solution. Estimated total fuel taxes paid in the base solutions ranged from $542,499 in 1987 to $578,789 in 1988. About 70 percent of total road taxes were paid by automobiles in each year.

Abandoning the Green Mountain line resulted in only a slight increase in road use tax revenue, while abandonment of the Albion-Liscomb line increased road use taxes paid by $15,739 to $21,009. The new grain elevator reduced road use tax revenue by about $13,000 in 1986 and $19,000 in 1987 and 1988. The new elevator resulted in a substantial reduction in both farm-to-elevator and elevator-to-market grain shipments by truck.

Upgrading S-75 north of U.S. 30 had essentially no impact on motor fuel tax revenues. However, this study did not evaluate the amount of traffic this investment would have diverted from U.S. 14 through Marshalltown. Paving S-75 south of U.S. 30 reduced the amount of motor fuel taxes paid in both solutions by about $300 to $600 per year.

NET BENEFITS TO SOCIETY

Tables 40, 41, and 42 show the aggregated net benefits to society from the six solutions for 1986, 1987, and 1988. The Green Mountain abandonment resulted in total net benefits of about $139,000 to $145,000 per year. Most of the benefits accrued to the railroad from rail line maintenance savings and salvage value of the rail line. The railroad company received benefits of about $147,000 per year from maintenance cost savings and the annualized salvage value of the track and right-of-way.

The abandonment of the Albion-Liscomb branch line resulted in a large net loss to society in all three years. The large net loss in 1987 of $259,323 occurred because 1987 rail bids for grain were high relative to truck bids. The net losses in 1986 and 1988 were $84,935 and $71,572, respectively. Thus, the net value of a branch line to society varied from year-to-year, depending on the prices of grain at the relevant truck and rail markets. Grain farmers were the large losers from the Albion-Liscomb abandonment. Moreover, gross revenues to elevators declined substantially in each of the three years.

The railroad company, on the other hand, realized an annualized benefit of $153,054 in 1986 and $148,794 in 1987 and 1988 from the salvage value of the branch line within Marshall County and from maintenance savings. There were losses to society from additional highway

Table 39. Estimated Change in Motor Fuel Tax From the Previous Solution by Year

Year	Vehicle type	Base solution	Change from previous solution: Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North of U.S. 30	Pave S-75 South to E-63	Pave S-75 to county line
1986								
	Automobile	$393,514	$ 0	$ 0	$ 0	$ 0	$ -114	$ -52
	Single-axle	61,921	0	163	-5	2	5	-25
	Tandem-axle	10,442	0	399	-1,042	-22	-13	-84
	Semi	88,872	246	15,177	-11,892	-71	-122	-482
	Total	$554,749	$246	$15,739	$-12,938	$ -90	$ -244	$ -642
1987								
	Automobile	$393,514	$ 0	$ 0	$ 0	$ 0	$ -114	$ -52
	Single-axle	61,600	0	330	-306	-8	1	-7
	Tandem-axle	9,439	0	137	-516	-29	-26	-10
	Semi	77,947	804	19,597	-18,075	-112	-213	-512
	Total	$542,499	$804	$20,064	$-18,897	$-148	$ -352	$ -581
1988								
	Automobile	$393,549	$ 0	$ 0	$ 0	$ 0	$ -114	$ -58
	Single-axle	61,744	0	125	-112	1	3	-8
	Tandem-axle	8,068	0	868	-741	-8	-25	-14
	Semi	115,428	518	20,017	-18,219	-135	-494	-507
	Total	$578,789	$518	$21,009	$-19,072	$-141	$ -630	$ -587

Table 40. Estimated Change in Net Benefits to Society From the Previous Solution, 1986

Benefit recipient	Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
	Change from previous solution					
Revenue to grain farmers	$ -68	$-146,877	$147,971	$ 1,380	$ 9,935	$ 2,108
Revenue to grain elevators	-2,032	-72,704	110,464	1,712	1,136	800
Fertilizer deliveries to farms	0	0	0	2	21	11
Fertilizer deliveries to dealers	0	0	0	0	0	0
Other farm travel	0	0	0	99	74	415
Household and overhead travel	0	0	0	84,233	10,076	3,504
Railroad						
Salvage value	98,193	111,113	0	0	0	0
Maintenance savings	49,021	41,941	0	0	0	0
Elevator construction	0	0	-201,582	0	0	0
Highway						
Construction	0	0	0	-427,743	-106,068	-159,101
Maintenance	-522	-11,659	12,950	8,647	-32	137
Safety	-332	-22,488	18,233	270	483	2,879
Motor fuel tax revenues	246	15,739	-12,938	-90	-244	-642
Net benefits	$ 144,506	$ -84,935	$75,098	$-331,490	$ -84,457	$-149,889

Table 41. Estimated Change in Net Benefits to Society From the Previous Solution, 1987

Benefit recipient	Change from previous solution: Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
Revenue to grain farmers	$ -120	$-252,204	$ 187,175	$1,453	$ 11,187	$ 1,983
Revenue to grain elevators	-5,888	-130,736	105,392	1,392	832	111
Fertilizer deliveries to farms	0	0	0	2	17	8
Fertilizer deliveries to dealers	0	886	0	-44	0	0
Other farm travel	0	0	0	95	73	404
Household travel	0	0	0	84,233	10,076	3,504
Railroad						
Salvage value	98,193	111,113	0	0	0	0
Maintenance savings	49,021	37,681	0	0	0	0
Elevator construction	0	0	-201,582	0	0	0
Highway						
Construction	0	0	0	-427,743	-106,068	-159,101
Maintenance	-1,618	-19,854	15,375	7,665	25	139
Safety	-1,044	-26,813	25,498	288	281	578
Motor fuel tax revenues	804	20,604	-18,897	-148	-352	-581
Net benefits	$139,348	$-259,323	$ 112,961	$-332,807	$ -83,929	$-152,955

Table 42. Estimated Change in Net Benefits to Society From the Previous Solution, 1988

Benefit recipient	Change from previous solution: Green Mountain abandonment	Albion-Liscomb abandonment	New grain elevator	Upgrade S-75 North	Pave S-75 from U.S. 30 to E-63	Pave S-75 from E-63 to county line
Revenue to grain farmers	$ -98	$-114,102	$142,847	$ 1,379	$ 7,493	$ 1,378
Revenue to grain elevators	-2,488	-93,200	120,784	856	72	48
Fertilizer deliveries to farms	0	0	0	2	18	8
Fertilizer deliveries to dealers	0	415	0	-20	0	0
Other farm travel	0	0	0	98	96	516
Household and overhead travel	0	0	0	84,233	10,076	3,504
Railroad						
Salvage value	98,193	111,113	0	0	0	0
Maintenance savings	49,021	37,681	0	0	0	0
Elevator construction	0	0	-201,582	0	0	0
Highway						
Construction	0	0	0	-427,743	-106,068	-159,101
Maintenance	-987	-7,078	12,447	5,129	226	19
Safety	-622	-27,410	24,507	325	652	580
Motor fuel tax revenues	518	21,009	-19,072	-141	-630	-587
Net benefits	$143,537	$ -71,572	$ 79,911	$-335,882	$ -88,065	$-153,635

maintenance and safety costs of $34,147 to $46,667 per year. However, motor fuel tax revenues exceeded additional road maintenance costs.

The new elevator constructed on the main rail line after the abandonment of the Albion-Liscomb branch line resulted in net benefits of $75,098 in 1986, $112,961 in 1987, and $79,911 in 1988. The larger benefits in 1987 were the result of the high rail bids relative to truck bids in 1987. Revenue to farmers and elevators increased substantially from the new elevator in each of the three years. However, the annualized construction cost of the new elevator was $201,582.

Adding the three years of farm revenue together, the new elevator restored all but $35,476, or 0.04 cents per bushel, of the lost farmer grain revenue from the Green Mountain and Albion-Liscomb abandonments. Over the three years, the new elevator solution generated almost $30,000 more revenue to elevators than was lost by the two rail abandonment solutions. However, most of the restored elevator revenue went to the new elevator. Thus, the major losers from the Albion-Liscomb abandonment after construction of the new elevator--were the Albion, Liscomb, and surrounding elevators.

The new elevator eliminated most of the increased road maintenance costs and increased most of the safety costs resulting from the Albion-Liscomb branch line abandonment. However, the new elevator reduced motor fuel tax revenues by $12,938 to $19,072 per year.

In terms of total net benefits to society, the new elevator was able to recover about 99 percent of losses attributable to the Albion-Liscomb abandonment in 1986 and 1988 combined. In 1987, however, the new elevator was able to recapture only about 44 percent of the loss from the previous solution. Again, this was largely due to the loss of the high 1987 rail bids in the Albion-Liscomb abandonment.

Upgrading S-75 north resulted in a substantial net loss to society in all three years. There were only minor benefits to farmers, elevators, households, safety and road maintenance costs. There was an average of 1,927 overhead trips per day on S-75 north. These overhead trip shares for automobile and pickups, single axle, tandem axle and tractor semi-trailer trucks were 92.5, 2.3, 1.2, and 4.0 percent, respectively. The major benefit of upgrading S-75 north was a $84,233 per year reduction in household and overhead traffic costs. However, the annualized road construction costs were $427,743 per year, which created a net loss to society of approximately $333,000 per year.

Paving S-75 from U.S. 30 to E-63 resulted in a loss to society of approximately $85,000 per year. This paving resulted in higher net revenues to farmers and elevators along with small reductions in fertilizer and other farm product delivery costs. There was also a reduction in household travel costs as vehicle miles and vehicle operating costs per mile declined, resulting from shorter paved distances to Marshalltown and other destinations. These shorter distances also resulted in road maintenance and safety cost savings. However, the annualized construction costs were far greater than the travel savings in all three years.

The paving of S-75 from E-63 south to the county line resulted in a net loss to society of approximately $153,000 per year. This paving created household travel savings of approximately $3,500 per year as well as small increases in farm and elevator revenues. However, the annualized construction cost of $159,101 per year was about $153,000 greater than the net benefits from the paving.

CONCLUSIONS AND IMPLICATIONS

Although the case study results presented above are, to a great extent, due to local conditions, several important conclusions and general public policy implications can be drawn from this analysis.

First, previous studies and public programs, focusing exclusively on railroad or highway investment, miss the possibilities for improving the overall efficiency of local surface transportation systems achievable through a more broadly based, integrated analysis of rail, highway, and distribution facility alternatives.

Second, most of the benefits of railroad abandonment accrue to railroads in the form of reduced maintenance costs and increased returns on repositioned assets. The major adverse impacts of railroad abandonments fall on farmers and local agricultural enterprises. With the establishment of a new unit-train grain loading elevator, well positioned to serve areas losing branch line rail service, these adverse distributional impacts on farmers and local businesses can be offset. Although a new grain loading elevator would reverse the adverse impacts of the branch line abandonments on elevators in the aggregate, most of the restored elevator benefits would go to the new elevator. One way for existing elevators to capture the benefits of the new elevator would be to cooperatively invest in the new elevator. This type of cooperative investment has already occurred in other areas in Iowa.

Third, for rural areas which already possess an extensive network of paved roads, paving additional roads or upgrading existing paved roads by widening lanes or improving shoulders does not yield adequate benefits to offset the cost of making such improvements. However, in areas bordering larger cities that are experiencing residential development, such improvements may be justified by the traffic from increased population or as a bypass for traffic currently routed through cities.

Fourth, railroad abandonments have major impacts on agriculture and only minimal impacts on non-farm travel. However, changing the rural road network results in reductions in costs for both farm-based and household travel. Although this study found benefits were inadequate to justify any of the proposed road system improvements, areas with lesser amounts of existing paved roads may have different results. Also, the paving of gravel roads may become justified in urban fringe areas as population density increases.

Fifth, railroad abandonments can have significant safety consequences for motor vehicle transportation. This impact has been largely ignored in previous studies.

Sixth, the order of evaluating investment strategies has an impact on the research results. For example, the grain train loading elevator investment was made after the two rail lines were abandoned. If the new elevator investment had been made prior to the two abandonments, the net benefits to the new elevator would have been sharply lower. Logically, however, the investment should not have been considered prior to abandonment.

And, finally, the amount of travel diverted from railroads to highways resulting from railroad abandonments does not have a major effect on highway maintenance costs. The impact of increased truck traffic on highways when calculated on a marginal, or attributable, cost basis is generally offset by the additional motor fuel tax revenues generated by this traffic.

This last conclusion contradicts generally held beliefs regarding the impacts of trucks on highway maintenance costs. This apparent conflict results from two sources. First, most prior studies have computed the impact of trucks on highway maintenance and construction costs on a fully allocated cost basis. However, a large share of the costs associated with the maintenance of existing roads are common costs and should be shared by all users. Furthermore, prior studies have directly attributed reconstruction and resurfacing cost to axle loadings. In reality, however, some portion of reconstruction costs are common costs and should therefore be attributed to all users. Therefore, only incremental costs directly attributable to increased truck traffic should be included in railroad abandonment impact analysis.

Second, only legal truck weights were considered in this analysis. Much of the highway road damage attributable to truck traffic hauling agricultural commodities to market may be due to vehicle weights above legal loads limits. Since road damage increases at a greater than proportional rate as axle loadings increase, excessively heavy loads may be responsible for a large share of highway damage. This is a topic which merits further study but was beyond the scope of this research.

As a result of this project, several other issues deserving additional research identified include: (1) relationship between the number and severity of motor vehicle accidents and factors such as vehicle mix, vehicle type, and road condition; (2) transferability of rural trip factors from one area to another; and (3) amount and quality of information needed to make meaningful local rural surface transportation investment decisions.

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APPENDIX A

MATHEMATICAL MODELS AND COMPUTER ROUTINES

This appendix presents the mathematical models and computer routines which made up the program used to estimate the impacts different investment strategies had on branch rail lines and local rural road systems. The program determines the: (1) distribution of grain shipments by farmers; (2) distribution of grain shipments by elevators; (3) routes taken from farms to elevators; (4) routes taken from elevators to markets; (5) routes taken for household trips; and (6) total mileage and travel costs.

FARM-TO-ELEVATOR MODEL

The computer program was designed to maximize net revenue to farms by shipping grain from each farm zone to the elevator with highest bid price net of shipping cost. The program calculated the monthly grain shipments by farms based on actual monthly distribution of receipts by elevators from farms. The percent of grain receipts by month and each vehicle type was obtained by a survey of Marshall County elevators. Using these distributions, the program calculated the farm-to-elevator shipments by each vehicle type. Given the amount of grain shipped from each zone by month and the bids from elevators, it was possible to determine the routes taken by each of the five different classes of vehicles along with each farm zone's grain revenue.

ELEVATOR-TO-MARKET MODEL

This model was designed to maximize the net revenue to elevators when shipping grain to markets. The bid prices from markets were placed into two data sets, one for rail bids and the second for trucks bids. The program determined which net truck or rail bid was greater. If the truck (rail) bid was greater than the rail (truck), the grain was sent to that market by truck (rail), and the revenue for the elevator was the FOB truck (rail) bid multiplied by the quantity of grain shipped.

OTHER TRAVEL MODEL

The purpose of this model was to estimate the costs and mileage accrued to household-related and non-grain agricultural-related trips. Several categories of household trips, identified in Table 34 of this report, were modeled in this study. The household-related trip data were derived from a previous study by Baumel, Hamlett and Pautsch (1986). In the 1986 study, Linn County household travel data were obtained from a census of rural Linn County households. A random sample of 100 households was extracted from the Linn County survey and used as a basis for estimating Marshall County household travel.

SHORTEST ROUTE ALGORITHM

A network model used to determine routes between farm zones and elevators and between elevators and markets found the minimum cost route from each origin to each destination for each vehicle type. A network consists of a set of nodes (intersections) connected by a set of arcs (roads). A node represents a location where a trip originates relays or terminates. Arcs are pathways of known length which allow traffic to flow between nodes.

To determine the minimum shipping cost route from farm to elevators and elevators to markets, assume that a cost parameter (c_{ij}) is associated with each arc (i, j). Dummy or "free" arcs would carry a cost $C_{ij} = 0$, while impossible arcs carry a cost $C_{ij} = \infty$. The problem discussed in this section can be interpreted as that of shipping one unit of a commodity at minimum cost from the source node S (farm) to the sink node T (elevator) of a given network. Mathematically, this problem can be formulated as a linear program as indicated in Equations (6), (7), (8), and (9):

$$\text{Minimize } \Sigma\ \Sigma\ C_{ij}F_{ij} \tag{6}$$

subject to:

$$\Sigma\ F_{sj} - \Sigma\ F_{js} = 1 \tag{7}$$

$$\Sigma\ F_{ij} - \Sigma\ F_{ji} = 0 \quad i{=}s,\ i{=}t \tag{8}$$

$$\Sigma\ F_{tj} - \Sigma\ F_{ji} = -1 \tag{9}$$

$$F_{ij} \geq 0$$

$$WT_{ij} \geq WG_V \tag{10}$$

C_{ij} = $\Sigma\Sigma\ f_{ij}\ Dist_{ij}\ (CPMG_V\ G_{ij} + CPMP_V\ H_{ij})$
= cost of making one round trip from origin S to destination T with vehicle V

F_{ij} = amount of traffic flowing from the i^{th} node to the j^{th} node

$CPMG_V$ = cost per mile of traveling over a gravel surface with vehicle V

$Dist_{ij}$ = distance from the i^{th} node to the j^{th} node

G_{ij} = 1 if the arc from the i^{th} node to the j^{th} node has a gravel surface; otherwise $G_{ij} = 0$

$CPMP_V$ = cost per mile of traveling over a paved surface with vehicle V

H_{ij} = 1 if the arc from the i^{th} node to the j^{th} node has a paved surface; otherwise $H_{ij} = 0$

WT_{ij} = weight constraint of the arc connecting the i^{th} node to the j^{th} node

WG_V = weight of vehicle V

i = beginning node

j = ending node

The first constraint guarantees that one unit of flow leaves the source. The second set of constraints ensures the conservation of this unit of flow as it moves through the network. The third constraint specifies that one unit of flow arrives at the terminal node. The minimal path can be identified as the connected sequence of arcs (i, j) such that $F_{ij} = 1$.

COMPUTER PROGRAM

A map of the road network was numbered at all nodes (intersections). For example, assume a highly simplified network consisting of 5 nodes, or intersections, and 5 arcs, or roads, connecting them, as shown in Figure 14.

Figure 14. Hypothetical road network.

```
1---------2-----------5
!         !
!         !
!         !
3----------4
```

The road network in Figure 14 was translated into a data set in Table 43. The data set consisted of the following items:

BN	=	beginning node
EN	=	ending node
DIST	=	the distance in miles from node (BN) to (EN)
ST	=	surface type
7000	=	cement
6000	=	asphalt
1000	=	gravel
CN	=	count number
BC	=	bridge capacity
0	=	no constraint, otherwise bridge load limit in tons

Table 43. Hypothetical Road Network

BN	EN	DIST	ST	CN	BC
3	1	2	6000	930	0
1	3	2	6000	930	0
4	3	2	6000	300	0
3	4	2	6000	300	0
2	4	2	1000	0	20
4	2	2	1000	0	20
1	2	2	7000	3000	0
2	1	2	7000	3000	0
5	2	2.5	7000	9000	0
2	5	2.5	7000	9000	0

The shortest route algorithm sorted the road network into the data set in Table 44 in order to simplify the operation of finding the best route.

Table 44. Sorted Hypothetical Road Network

BN	EN	DIST	ST	CN	BW
1	2	2	7000	3000	0
1	3	2	6000	930	0
2	1	2	7000	3000	0
2	4	2	1000	300	20
2	5	2.5	7000	9000	0
3	1	2	6000	930	0
3	4	2	6000	300	0
4	2	2	1000	0	20
4	3	2	1000	300	0
5	2	2.5	7000	9000	0

Next, the program developed a modified version of the sorted data set that contains the BN, EN, and pseudodistances over the arcs by each vehicle type. The pseudodistances modified the estimated vehicle travel costs to reflect the costs of traveling over different road surfaces. For example, using state roads as a standard, distances on gravel roads were increased 46 percent to reflect the increase in travel costs on gravel roads as compared to state roads. The pseudodistances were calculated by one of two methods.

First, each distance was converted to a pseudodistance for each type of vehicle for each surface type. Due to the differing cost of travel over varying surface types, determination of the best route required the units of comparison be in similar units. Pseudodistances were used to convert arc distances into units of state road equivalents. To change the distances to pseudodistances, surface adjustment factors were generated by calculating the ratios of the vehicle-mile cost on gravel surface to vehicle-mile cost on paved surfaces for each vehicle type. If the arc was a paved state road, the pseudodistance was equal to the actual distance of the arc. If the road was not a paved state road, then the pseudodistance was equal to the actual distance multiplied by the appropriate surface adjustment factor. The surface adjustment factors were calculated using Equation (11) which expressed the relative cost of traveling over a paved state road compared to road type y:

$$SAF = \frac{CPM_y}{CPMS} \tag{11}$$

SAF = surface adjustment factor

CPM_y = cost per mile on road type y

CPMS = cost per mile on a state road

Table 45 shows the adjustment factors for different vehicle types over each surface.

Table 45. Surface Adjustment Factors by Vehicle Type

Vehicle type	Adjustment factors	
	Paved county to state roads	Gravel county to state roads
Automobile	1.05	1.39
Trucks	1.05	1.46

The complete hypothetical data set used to find the shortest path for each of the vehicles when loaded and empty is given in Table 46. The variables in Table 46 are defined as follows:

LC = location in the data set
BN = origination node
EN = destination node
DIST = distance between the nodes
CAR = pseudodistance for a car to travel over the arc
SAE = pseudodistance for a single axle truck empty to travel over the arc
SAL = pseudodistance for a single axle truck to travel over the arc
TAE = pseudodistance for an empty tandem-axle truck to travel over the arc
TAL = pseudodistance for a loaded tandem-axle truck to travel over the arc
SME = pseudodistance for an empty tractor semi-trailer truck to travel over the arc
SML = pseudodistance for a loaded tractor semi-trailer truck to travel over the arc
TWE = pseudodistance for a tractor and one empty wagon to travel over the arc
TWL = pseudodistance for a tractor and one loaded wagon to travel over the arc
TWWE = pseudodistance for a tractor and two empty wagons to travel over the arc
TWWL = pseudodistance for a tractor and two loaded wagons to travel over the arc

Table 46. Hypothetical Cost Data by Vehicle Over Arcs

LC	BN	EN	DIS	CAR	SAE	SAL	TAE	TAL	SME	SML	TWE	TWL	TWWE	TWWL
1	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	3	2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2	2	2	2
3	2	1	2	2	2	2	2	2	2	2	2	2	2	2
4	2	4	2	2.1	2.8	2.9	2.9	2.9	2.9	999	2.2	2.2	2.2	999
5	2	5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
6	3	1	2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2	2	2	2
7	3	4	2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2	2	2	2
8	4	2	2	2.8	2.8	2.9	2.9	2.9	2.9	999	2.2	2.2	2.2	999
9	4	3	2	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2	2	2	2
10	5	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

In Table 46, a pseudodistance of two was applied to a loaded tractor semi-trailer truck traveling from node 1 to node 2 over a paved state arc. Since this arc was a paved state road, no surface adjustment factor was applied; hence, the pseudodistance and the actual distance remained the same. The arc in line 2 of Table 46 gives a pseudodistance of 2.1 miles for a loaded tractor semi-trailer truck moving from node 1 to node 3, even though the actual distance is only two miles. This arc is a paved county road and therefore requires application of a surface adjustment factor. The SML pseudodistance value of 999 for the arc from the node 2 to node 4 indicates that a loaded tractor semi-trailer truck exceeds the maximum capacity of the bridge on the arc. The pseudodistance is set equal to 999 to prevent any loaded tractor semi-trailer truck from crossing the restricted arc. The bridge restrictions on each arc were checked for each vehicle on each arc. If the vehicle could legally cross the bridge on the arc, the distance was not changed. However, if the vehicle weight exceeded the posted bridge weight, the distance was changed to a pseudodistance of 999.

To improve the efficiency of Dijkstra's algorithm, the locations of beginning nodes in the data set were identified in Table 46 and supplied to an additional data set. This process produced the data set that appears in Table 47. Dijkstra's algorithm developed the shortest route tree or route by fanning out from the origin. The program was assigned a source node in the network and began an iterative procedure on the costs of traveling from the source node to all the other nodes in the network.

Table 47. Locations of Nodes in the Data Set

Node	Initial Line	Final Line
1	1	2
2	3	4
3	6	7
4	8	9
5	10	10

Table 47 tells the program which lines in the data set are assigned to each beginning node. Node 1 appears as a beginning node in lines 1 and 2 of Table 46. Table 47 also tells the program that node 5 appears only once in initial line 10 and the final line 10. This data set provided Dijkstra's algorithm with a guide to the location of nodes that were connected to a particular beginning node. This modification eliminated the need for a distance matrix. There were nearly 500 nodes in the Marshall County study area which would require a distance matrix with 500 rows and 500 columns. This alteration reduced the required storage by more than ten times and greatly increased the efficiency of Dijkstra's algorithm.

The final result was the minimized pseudodistance of traveling from the source node to all the other nodes in the network. But upon closer inspection, other minimal routes were being obtained. Dijkstra's algorithm operates on the logic that if a shortest path from the source node to node j is known, and if node i belongs to this path, then the minimal path from the source node to node i is known, and it is the portion of the original path ending at the i^{th} node.

The advantage of this procedure is that once an arc is part of the tree, it never leaves the tree, and, once a node value is permanently assigned, it does not change. Therefore, the shortest route to all permanently labeled nodes is known, regardless of whether or not the remaining nodes are labeled. The computer model, when supplied a source node, calculated the costs from the source node to all the other nodes in the network. The algorithm checked to see if the minimized-cost route between any of the origin-destination pairs lies on the minimized-costs path from the source node to any other node in the network. If the origin destination pair was on any of these routes, all the minimized-pseudodistance routes between the origin and destination had been calculated.

The algorithm found the minimum distance and corresponding route from a source node to all other nodes in the network. The algorithm assigned a temporary label and a permanent label to each node in the network. The temporary label represented an estimate of the shortest pseudodistance from a source node to each other node. Once a temporary label can no longer be improved, it is declared permanent. The permanent label represents the minimum distance from the source node to that node.

Initially every node except the source node was given a temporary label equal to the distance of the arc connecting the node directly to the source node. If the node was not directly connected to the source node, the node was given a temporary label equal to infinity. The permanent label of the source node was set equal at zero and the permanent label of the remaining nodes was calculated by the following iterative procedure:

<u>Step I</u>: Inspect all temporary labels of the nodes not previously declared permanent. Declare the node with the minimum temporary label as permanent and set its permanent label equal to the value of its temporary label.

<u>Step II</u>: Compare the remaining temporary label and the direct distance from the last node declared permanent to the nodes under consideration. The minimum of these two values is the new temporary label for that node. Then repeat Step I.

This procedure continued until all the nodes had been declared permanent. Once a node was assigned a permanent label, its temporary label was excluded from the calculations in Step II.

The algorithm simply worked backwards to find the distance minimizing route from the source node to some node j (ending node). It compared the permanent label of node j to the sum of the direct distance from some node i. If these two values were equal, then node i was used in finding the shortest distance from the source node to node j and was, therefore, part of the route. This routine was repeated until the entire route was found.

The routes that were needed for this study were calculated by supplying the source node i (farm locations) and the destination node j (elevator locations). The program started at each farm node and found the routes to all the nodes in the road network. When the node happened to be the location of an elevator, the program output the route to a data set that resembles Table 48. Each route contained the farm location, the elevator location, the distance between the two, and the number of each arc of the route. Arc numbers were the beginning node and ending node for that arc. Data sets were generated for each empty and loaded vehicle type. The results from the process of finding the routes between the farm and the elevators were then used in all later programs. Assuming a farm at node 3 and node 4 and an elevator at node 1 and node 5, the data set for three of the vehicle types is given in Table 48.

Table 48. Optimal Routes Between Farms and Elevators for Three Vehicle Types

Vehicle Type	ORIG	DEST	PDST	Arc_1	Arc_2	Arc_3	Arc_4	Arc_5
Auto-	3	1	2.1	3001	0	0	0	0
mobile	3	5	6.6	3001	1002	2005	0	0
	4	1	4.1	4003	3001	0	0	0
	4	5	4.8	4002	2005	0	0	0
Empty	3	1	2.1	3001	0	0	0	0
semi-	3	5	6.6	3001	1002	2005	0	0
tractor	4	1	4.1	4003	3001	0	0	0
trailer	4	5	4.9	4002	2005	0	0	0
truck								
Loaded	3	1	2.1	3001	0	0	0	0
semi-	3	5	6.6	3001	1002	2005	0	0
tractor	4	1	4.1	4003	3001	0	0	0
trailer	4	5	8.7	4003	3001	1002	2005	0
truck								

The variables presented in Table 48 are defined as follows:

ORIG = node number where a farm is located

DEST = node number where a elevator is located

PDST = total pseudodistance for traveling from the origin (farm) to the destination (elevator)

Arc_n = the beginning node (BN) plus the ending node; is the first space of the 4 spaces; the ending node (EN) is the remaining three spaces

As shown in Table 48, the program determined that the best route for an empty tractor semi-trailer truck to travel from the farm at node 3 to the elevator at node 1 was a direct route on arc 3001. In this case, the route required only one arc. For an automobile to travel from the farm at node 3 to the elevator at node 5, the program determined that the minimum pseudodistance route was from node 3 to node 1 (Arc_1 3001), then from node 1 to node 2 (denoted in Table 48 as Arc_2 1002), then from node 2 to destination node 5.

The bridge constraint on the arc between node 4 and node 2 restricts the loaded tractor semi-trailer truck from passing when moving from farm (origin) node 4 to elevator (destination) node 5. As a result, the program routed the loaded tractor semi-trailer truck differently from the empty tractor semi-trailer truck. The route had a pseudodistance of 8.7 for a loaded trip and 4.9 for an empty trip.

MAXIMUM NET FARM REVENUE MODEL

Equation 12 maximizes net farm revenue from the sale of corn and soybeans:

$$\text{Maximize } \left(\sum_{f}\sum_{e}\sum_{t}\sum_{v}(FB_{et}-TFE_{fev})Q_{ftv}\right) \quad (12)$$

where:

Q_{ftv}	=	quantity of grain sold by farm f in time period t by vehicle type v
FB_{et}	=	farm bid at elevator e during time period t
TFE_{fev}	=	transport cost from farm f to elevator e using v
f	=	farms
e	=	elevators
v	=	vehicles used to ship grain from farm to elevator 1. single axle trucks 2. tandem axle trucks 3. semi-trailer trucks 4. farm tractor with one wagon and two wagons
t	=	time period 1,...,13

Elevator revenue was maximized using Equation 13:

$$\text{Maximize } \left[\left(\sum_{e}\sum_{m}\sum_{s}\sum_{t}(Q_{et}PM_{emst}\right)\right] \quad (13)$$

subject to:

Q_{et}	=	$Q^T_e * P_{et}$
Q_{et}	=	quantity of grain shipped from elevator e during the time period t
Q^T_e	=	total quantity of grain received at elevator e
P_{et}	=	percent of the total quantity of grain shipped by elevator e during time period t
PM_{emst}	=	market price for elevator e for market m by mode s (rail or semi) in time period t

e	=	elevator location e = 1,...,33
m	=	market m = 1,...,8
s	=	mode of shipment, 0 = truck, 1 = rail
t	=	time period t = 1,...,13

MINIMIZING OTHER TRAVEL COSTS

The first step in applying the Linn County data to the Marshall County study was to estimate the average number of trips per household in each urban or rural group for each trip type. These averages can be found in Table 10. The total number of household trips made by each 2x2 mile farm in Marshall County was estimated by multiplying the number of households per 2x2 mile Marshall County area by the respective Linn County average for each of the respective trips types as shown in Equation (14):

$$MCT_{t,f,g} = MCH_{f,g} * (LCT_{t,g} / LCH_g), \quad f = 1..144 \tag{14}$$

$t = 1..7$
$g = 1..2$
$1 =$ urban
$2 =$ rural

where:

$MCT_{t,f,g} =$ the number of Marshall County trips of trip category t supplied by farm f in group g

$MCH_{f,g} =$ the number of households in Marshall County contained in 2x2 mile farm f in group g

$LCT_{t,g} =$ the number of trips in group g of category t in the sample taken from the Linn County study area

$LCH_g =$ the number of households in group g in the sample taken from the Linn County study area

Once the number of household trips per 2x2 mile farm was established, it was necessary to determine the locations of the trip origin and destinations where the trips originated and terminated. Retail sales tax collection data contained in Table 11 were used to determine the destinations for shopping trips. Marshalltown alone generated about 90 percent of Marshall County's total retail sales tax collections. Therefore, Marshalltown was assigned 90 percent of all Marshall County shopping trips. The remaining 10 percent of county shopping trips were assigned to the town nearest the origin of the shopping trips.

Destinations for commuter trips in Marshall County were based on the location of manufacturing jobs. Table 12 contains a list of the locations of manufacturing jobs in Marshall County along with the percentage of manufacturing jobs in each location. Marshalltown contained about 95 percent of all Marshall County manufacturing jobs, while the remaining 5 percent were located throughout the rest of the county. Consequently, 95 percent of Marshall County commuter trips were assigned to Marshalltown, while the balance were assigned to the town nearest the origin of the commuting trips.

The last category of household-related trips was visitors and deliveries. In each case, a judgement was made on whether each type of delivery could be handled by small rural towns. If small towns were judged to be able to handle the delivery, then the town nearest the delivery destination was assigned to be the origin of the delivery. If not, then the delivery origin was assigned to Marshalltown.

The number of Marshall County farm-related trips per farm were calculated using Equation (15), with a slight modification. Rather than average the Linn County data by household, the Linn County averages for farm-related trips were calculated on a per farmable acre basis. Therefore, Marshall County farm-related trips were calculated in terms of number of trips per farmable acre.

Five non-grain farm commodities--milk, cattle, hogs, sheep, and fertilizer--were modeled in this study. Market destinations of livestock and milk were obtained from Iowa State University Extension livestock specialists. Table 7 contains the market locations and the percentage of each livestock class that was assigned to each market. Hogs and cattle were assumed to be shipped in tractor semi-trailer trucks with hauling capacities of 45,000 and 50,000 pounds, respectively. Milk was assumed to be transported in tandem-axle bulk tank trucks with a capacity of 30,000 pounds. Finally, sheep were delivered to market in the box of a pickup truck, 12 head per trip.

The number of trips made to market by each 2x2 mile farm was determined using Equation (15):

$$VT_{i,m,1} = NINT((MP_{m,l}*LP_{i,l})/TCAP_l) + .5) \qquad (15)$$

where:

$VT_{i,m,l}$ = vehicle trips from farm i to market m for livestock class 1

$LP_{i,l}$ = livestock production for farm i, livestock class 1^*

$MP_{m,l}$ = market percentage for market m, livestock class 1

$TCAP_l$ = hauling capacity of vehicle hauling livestock of class 1

NINT = the nearest integer function

The advantage of using the nearest integer function is that no partial trucks (i.e., 2.75 trucks) are included in the model. If a farm doesn't have the quantity to fill a truck, the model assumes a partially filled truck was sent to market (i.e., 2.75 truck loads was 3 trucks).

Origins of fertilizer delivered to fertilizer dealers were obtained from the survey of the Marshall County elevators. Most elevators handled fertilizer or had a fertilizer dealer in their vicinity; therefore, fertilizer deliveries to farms were shipped from the nearest elevator.

Once the origins and destinations were determined, the next step was to determine the minimum cost route for each vehicle trip. After determining the minimum cost routes for each farm, costs incurred by the traveler were calculated by vehicle type and by trip type.

Costs to travelers were calculated in a four-step process. The first step was to identify each segment in the minimum cost route as a rigid, flexible, or gravel surface. Second, the variable cost per vehicle mile for the appropriate surface type was multiplied by the length of the segment to obtain the variable cost per vehicle pass over that segment. The third step was to multiply the variable cost per vehicle pass by the number of annual vehicle passes to obtain an estimate of the annual variable cost of traveling over that segment of road. Finally, summing up the annual variable cost for each segment in the minimum cost route gave an estimate of the annual cost to the traveler for driving between each origin and destination.

Equations (16) and (17) were used to estimate variable travel costs by vehicle type and trip type:

$$\sum_{t}\sum_{h}\sum_{d}\sum_{i}(((R)(VCF_{r,v})(D_{i,h,d})+(F)(VCF_{f,v})(D_{i,h,d})+(G)(VCF_{g,v})(D_{i,h,d}))(Q_{v,t,h,d})) \qquad (16)$$

$$\sum_{v}\sum_{h}\sum_{d}\sum_{i}(((R)(VCF_{r,v})(D_{i,h,d})+(F)(VCF_{f,v})(D_{i,h,d})+(G)(VCF_{g,v})(D_{i,h,d}))(Q_{v,t,h,d})) \qquad (17)$$

where:

t	=	trip type, t = 1..19
v	=	vehicle type, v = 1..5
d	=	destination
h	=	household number
R	=	1 if $D_{i,h,d}$ is a rigid surface, 0 if not
F	=	1 if $D_{i,h,d}$ is a flexible surface, 0 if not
G	=	1 if $D_{i,h,d}$ is a gravel surface, 0 if not
r	=	rigid surface
f	=	flexible surface
g	=	gravel surface
i	=	road segment number in the minimum cost route
VCF	=	variable cost factor
D	=	length of the rod segment in the minimum cost route
Q	=	number of passes over the minimum cost route

Each iteration on V of Equation (16) gave the total cost by each type of vehicle. Each iteration on t of Equation (17) gave the total cost by each type of trip.

Estimates of total miles traveled were estimated by (1) vehicle type, (2) trip type, and (3) road surface type. Estimating the mileage was a three-step process. Step one involved determining the origins and destinations associated with each trip type. Step two involved using the origin/destination data to estimate the minimum cost route associated with each trip. Once the minimum cost routes were determined, step three involved each of the following Equations (18), (19), and (20) used to estimate each of the respective total mileage:

$$\sum_{t}\sum_{h}\sum_{d}\sum_{i}(D_{i,h,d})(Q_{v,t,h,d}) \tag{18}$$

$$\sum_{v}\sum_{h}\sum_{d}\sum_{i}(D_{i,h,d})(Q_{v,t,h,d}) \tag{19}$$

$$\sum_{v}\sum_{t}\sum_{h}\sum_{d}\sum_{i}(D_{i,h,d})(Q_{v,t,h,d})(ST_{i}) \tag{20}$$

where:

v	=	vehicle type, v = 1..5
t	=	trip type, t = 1..19
s	=	surface type, s = 1..3
h	=	origin number
d	=	destination number
i	=	segment number in the minimum cost route
$D_{i,h,d}$	=	length of segment i in the minimum cost route
$Q_{v,t,h,d}$	=	number of passes by vehicle type v, type t, from origin h to destination d
ST_i	=	1 if surface type of $D_{i,h,d}$ is equal to s
	=	0 if surface type of $D_{i,h,d}$ is not equal to s

Each iteration of Equation (18) on v gave the total mileage per vehicle type; each iteration of Equation (19) on t gave the total mileage per trip type; and each iteration of Equation (20) on s gave the total mileage per road surface type.

APPENDIX B

PROCEDURE FOR ESTIMATING TRAVEL COSTS ON PAVED, GRANULAR AND EARTH SURFACE ROADS

All vehicles were placed in one of six categories based on axle weights. The categories were automobiles, single axle trucks, tandem axle trucks, tractor semi-trailer trucks, tractors with one wagon and tractors with two wagons. The procedures used to estimate each cost component taken from Hansen, Hamlett, Pautsch and Baumel are as follows.

Fuel Costs

Fuel costs, in cents per mile, for each registered vehicle type were estimated as in Equation (21):

$$F_i = [FP_i][FC_i]^{-1} \tag{21}$$

where:

F_i = fuel cost, in cents per mile, for vehicle type i
FP_i = fuel price, in cents per gallon, for vehicle type i
= \$1.30 per gallon for gasoline
= \$1.16 per gallon for diesel for registered vehicles
= \$0.57 per gallon for diesel for farm tractors
FC_i = fuel consumption, in miles per gallon, for vehicle type i

For tractors, fuel consumption in miles per gallon was defined as the ratio of speed in miles per hour divided by fuel consumption in gallons per hour in Equation (22):

$$FC_i = [S_i][G_i]^{-1} \tag{22}$$

where:

S_i = speed in miles per hour
G_i = fuel consumption, in gallons per hour

Relationships between G_i and the percent engine load for vehicle type i (EL_i) were estimated using least squares regression procedures and was used to estimate G_i for each vehicle type. The estimate for EL_i was obtained from Equation (23):

$$EL_i = V_i + (D_i * S_i)/375 \tag{23}$$

where:

V_i = percent of engine load for vehicle i with no trailing wagons
D_i = the draft of vehicle type i is defined in Equation (24):

$$= C_i * A_i \tag{24}$$

where:

C_i = adjustment coefficient to convert the weight of equipment being pulled by the tractor on a specified surface type to vehicle draft
A_i = weight of wagon being pulled by vehicle type i

Oil Costs

Oil cost in cents per mile for each vehicle type were calculated as follows in Equation (25):

$$O_i = OP_i * OC_i \qquad (25)$$

where:

O_i = oil cost in cents per mile for vehicle type i
OP_i = oil prices per unit for vehicle type i
OC_i = oil consumption, in quarts per mile, for vehicle type i. For tractors, oil consumption in gallons per mile was defined in Equation (26):

$$= [OM_i][S_i]^{-1} \qquad (26)$$

where:

OM_i = oil consumption in gallons per hour was taken directly from the Agricultural Engineering Yearbook (1981-1982) and is defined in Equation (27):

$$= 0.00573 + 0.00021\ H_i \qquad (27)$$

where:

H_i = engine horsepower
S_i = speed in miles per hour

Tire Costs

Tire cost, in cents per mile, for each vehicle type was estimated as follows in Equation (28):

$$T_i = [N_{ik} * TP_{ik}]\ L_{ik}^{-1} \qquad (28)$$

where:

T_i = tire cost, in cents per mile, for vehicle type i
k = type of tire (i.e. front, rear, trailer tires)
N_{ik} = number of the tire type k on vehicle type i
TP_{ij} = price of tire type k on vehicle type i
L_{ik} = expected life in miles of tire type k for road vehicle type i

For tractors, the expected life in miles of tire type k was defined in Equation (29):

$$L_{ik} = M_{ik} * S_i \qquad (29)$$

where:

M_{ik} = expected life, in hours, of tire type k for vehicle i
S_i = speed, in miles per hour, for vehicle type i

Maintenance Costs

Maintenance and repair cost in cents per mile for registered vehicles were taken from previous studies whenever possible. In those cases where maintenance and repair cost for road vehicles were not available, maintenance costs for vehicle type i were estimated by Equation (30):

$$MC_i = R_i\,[AM_i]^{-1} \qquad (30)$$

where:

MC_i = maintenance and repair cost, in cents per mile, for vehicle type i
R_i = average annual maintenance and repair cost, in cents, for road vehicle type i
AM_i = average annual miles driven by road vehicle type i

Maintenance and repair cost, in cents per mile, for tractors was estimated by Equation (31):

$$MC_i = R_i\,[AM_i]^{-1} \qquad (31)$$

where:

R_i = estimated total lifetime maintenance and repair cost for tractors

<u>The Agricultural Engineers Handbook</u> (1981-1982) estimates R_i to be Equation (32):

$$= (0.120)(VP_i)(Q_i/1000)^{2.033} \qquad (32)$$

AM_i = total lifetime tractor miles and is estimated by Equation (33):

$$= Q_i * S_i \qquad (33)$$

where:

R_i = total lifetime repairs, in cents
VP_i = list price of tractor
Q_i = estimated life, in hours, of tractor
S_i = speed, in miles per hour, of tractor

Travel Time Component

Variable travel cost in cents per mile for each vehicle type was calculated in Equation (34):

$$TT_i = (NA * W_i)\,(S_i)^{-1} \qquad (34)$$

where:

TT_i = travel time cost, in cents per mile, for vehicle type i
NA_i = average number of adults in vehicle type i
W_i = estimated value of the adults time, in cents per hour, for vehicle type i; a rate of $6.00 per hour was used for operators of elevator and farmer owned trucks
S_i = speed in miles per hour of vehicle type i

Variable Costs by Surface Type

The fuel, oil, tire, maintenance, and travel time cost components were estimated for each road vehicle and then summed to arrive at a "base" variable cost function. "Base" variable cost estimates were assumed to have 100 percent of travel on paved surfaces. Each base variable cost function was then adjusted to state paved, county paved, and gravel surface variable cost functions by using Winfrey's surface adjustment factors.

Winfrey's surface adjustment factors reflect the change in variable running cost that occur due to changes in surface types. These variable cost changes are the result of characteristics of the road surface such as firmness, abrasiveness, roughness, dustiness, and looseness of the surface. Winfrey's adjustment factors include fuel, oil, tires, maintenance, and depreciation. The travel time cost component was also included in the adjustment factors because of the speed differentials on different surface types.

Winfrey only provided surface adjustment factors for road vehicles. Consequently, the fuel, oil, tire, maintenance, and travel time costs for farm vehicles were estimated for each type of vehicle on both paved and gravel surfaces. The impact of surface type on variable costs is reflected in the estimated speed, engine load, draft, and tire wear. The estimated cost components were then summed by surface type to arrive at variable cost functions for each farm vehicle on paved and gravel surface.

Average Variable Cost Per Mile

Table 49 shows the average round-trip cost per mile by vehicle type and cost category on a state highway. Round trip costs would be 5 percent higher on a paved county road and 39-46 percent higher on a gravel road.

Table 49. Estimated Average Round Trip Variable Cost Per Mile by Type of Cost and Vehicle on State Highways

	Vehicle Type					
		Trucks			Tractor-wagons	
Cost	Automobile	Single axle	Tandem axle	Tractor semi-trailer	One wagon	Two wagons
Fuel	6.9	20.5	22.9	23.1	21.0	38.1
Oil	0.2	1.0	1.1	0.5	0.7	1.5
Tires	0.7	2.9	5.6	7.1	6.9	13.7
Maintenance	2.6	6.5	7.0	3.0	44.5	49.5
Travel time	9.8	16.8	16.8	16.8	56.9	56.9
Total variable cost	20.2	47.7	53.3	50.6	127.0	156.7