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THE ECONOMIC IMPACT OF RURAL ROAD DEVELOPMENT ON TRANSPORTATION ASSEMBLY COSTS IN AGRICULTURE

By

Jay Dean Tucker

A DISSERTATION

Submitted to
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ABSTRACT

THE ECONOMIC IMPACT OF RURAL ROAD DEVELOPMENT ON TRANSPORTATION ASSEMBLY COSTS IN AGRICULTURE

By

Jay Dean Tucker

The research work entitled "The Economic Impact of Rural Road Development on Transportation Assembly Costs in Agriculture" is designed to address problems in agricultural marketing and rural development which have long been neglected. The adequacy of rural roads to meet current and projected traffic needs is becoming increasingly important to agriculture and rural communities. Although road quality varies substantially, recent reports indicate that more than three-fifths of all U.S. rural arterial and collector (feeder) roads are identified as deficient. Moreover, one-half of the total U.S. rural feeder mileage is deemed unsuitable for sustained heavy truck traffic. Despite these reports, there has been a substantial disinvestment in rural road capital and maintenance programs. When deflated by an index of rural highway construction costs in the last 9 years, combined capital and maintenance expenditures have been cut by more than 30 percent. Recent and potential rail line abandonment decisions, especially in the Midwest, are placing additional stress on the nation's rural road system.

This thesis work investigates a localized rural transportation network in the State of Michigan. The methodology employed is a linear programming transportation model. With this model an investigation was

conducted into how the commodity flow pattern of grains changed and how aggregate transportation assembly costs were affected when changes occurred in the rural transport infrastructure.

The major hypothesis to be tested in this research is that improving the rural road network will lead to a significant economic impact upon agriculture and conversely a deterioration of the system will lead to severe economic consequences. In order to test this major premise or hypothesis a major grain producing county in Michigan which had a semi-developed rural road system was chosen for the study area. This county was Lenawee, a southeastern county in Michigan.

The initial methodological procedure was to computerize the entire transportation system in Lenawee County. To accomplish this, each intersection or major breaking point on the road and highway structure was assigned a coordinate point in the X, Y plane. Each section was assigned a number which corresponded to another computer file which contained survey information on the road section type, construction and condition. Based upon safety engineering standards, each segment was assigned a speed of travel. A computer algorithm then traced out the path from each production region to each grain elevator based upon minimizing time and distance. An average travel speed was then determined from the distance and time information for each path.

Utilizing transport cost data secured from the Interstate Commerce Commission, a schedule of transportation costs based upon the average operating speed was derived. This cost schedule was then used in assigning costs to each assembly path.

Grain shipments were based upon the 1977 production reported by Lenawee County. This production dictated the amount of grain to be moved over the rural transportation network. The effective capacity of each country elevator and final terminal destination served as the limiting constraints in the linear program.

Six investment scenarios were investigated in this research. These scenarios were: (1) maintaining the system as it now exists; (2) improving the system so that each earthen, gravel and tar-sprayed road was improved to an asphalt status; (3) no maintenance or construction on the county local roads over a 5 year period; (4) no maintenance or construction on the county local roads over a 10 year period; (5) no maintenance or construction on the county local roads over a 15 year period; and (6) no maintenance or construction on the county local roads over a 20 year period.

The empirical analysis showed little support for the major hypothesis tested. The total aggregate assembly transportation cost savings from improving the rural road system was $43,820.10. This was a cost savings of about 2 cents per bushel of grain moved in 1977. This cost savings must be compared to $1.7 million which represents the annual resources needed to improve the rural road structure used in this movement of grain. When the county local roads are allowed to deteriorate over a 5 year period, the cost to the grain producer is increased by $8,412.70 or slightly more than 0.4 cents per bushel. Allowing the local county roads to deteriorate another 5 years produces an added cost of $19,347.50 to transport costs. This represents approximately 0.9 cents per bushel in additional costs to the grain producer. The analysis indicates that at the 10th year of deterioration of the local county roads no further deterioration effect occurs on the transport infrastructure over the 15 and 20 year period. Improvement or deterioration of the rural road system showed little impact upon optimal commodity flow patterns. Total aggregate bushels of grain moved to each country elevator remained the same under each investment scenario. Only minor changes occurred in the movement of grain from producers to country elevators as a result of allowing the county local roads to deteriorate.

It appears from this analysis that the rural road infrastructure does not play as important a role in grain production movement as previously thought. It clearly indicates that grain production in this case study alone cannot justify increased investment in the rural road infrastructure. However, this analysis focused only upon one small user of the road system. Before any general policy statements concerning rural road development can be made, assessment of the economic impact upon other users must be made.

This general methodological approach can be employed in evaluating the economic benefits of other users of the system. Savings in commuting time or other travel time could be evaluated and added to the cost savings gained through added investment in rural roads. Other benefits, however, are outside of the scope of this model. These benefits would include such cost savings as reduced insurance rates from faster response times by local fire departments, crime prevention as a result of faster response time by local law enforcement agencies, etc. Negative externalities also occur with the development of the rural road system such as the promotion of urban sprawl, traffic congestion, noise pollution, etc.

Dedicated with love to my wife Sara Elizabeth

and daughter Ann Elizabeth

ACKNOWLEDGMENTS

Many people have contributed to the successful completion of this research thesis. Its completion could not have been attained without the support and encouragement of family, faculty and friends. I would like to break with the tradition of recognizing one's wife last and acknowledge first my wife Sara who contributed much to this effort. Without her support and loving encouragement this thesis would never have been finished. To her I owe much and greatly appreciate her patience, understanding and encouragement throughout my doctoral program.

To my major advisor and thesis chairman, Dr. Stanley R. Thompson, I owe a special acknowledgment. His constant guidance, constructive criticism and friendship throughout the writing of this thesis is acknowledged and appreciated.

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I owe a great debt to the Michigan Department of Transportation for providing the data without which this research could not have been accomplished. I especially wish to acknowledge the personnel of the Division of Planning who gave of their time and effort in helping to secure the data base for this research. Those most helpful were Mr. Richard Esch, Mr. Thomas Bordeaux, Ms. Karen Lindsay, Ms. Joyce Newell and Mr. Terry Gotts.

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The librarians at the Michigan State University Library were especially helpful in directing me to various documents and information contained in the library. I would like to especially acknowledge the help of Ms. Eleanor Boyles whose assistance in the government documents section is much appreciated.

To members of my guidance committee, Drs. Shaffer, Allen and Bonnen, I owe a debt for providing direction in my doctoral program. To all the faculty members whom I had in class or had the opportunity to interact with outside the classroom I owe a debt of thanks for the things which they have taught me.

I wish to express appreciation to my colleagues and friends at Michigan State University who encouraged me through their friendship. To Ms. Nancy Creed I wish to acknowledge her patience and constant care in typing this research manuscript.

Last, but not least by any means, I wish to express my appreciation and love to my parents, Jay and Eldora, for their interest and encouragement throughout my academic training. The family environment they

provided and encouragement and interest they have shown in me have greatly added to the success of this research. To them and my sisters, Joy and Janice, I express my appreciation for their support and encouragement.

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CHAPTER I

INTRODUCTION

An important aspect of the agricultural marketing system is the collecting and distributing of commodities and services. Before most goods and services can be utilized by consumers a transportation activity must normally take place. In agricultural production before land can be used it must be accessible and accessibility is a function of the changing technology of transportation and the transport infrastructure.[1] This study is designed to investigate one component of this marketing system, the movement of grain between agricultural producers and intermediate and final collecting points at grain elevators.

The transportation infrastructure influencing grain assembly movements in Michigan are rail lines, highways and roads. Michigan has been experiencing a decline, beginning in the 1920s, of the total mileage of rail lines serving the state. In 1974 Michigan had 5,963 miles of rail lines.[2] In that same year the state's highway and road system was comprised of 118,591 miles. The vast majority of this road system (83.2 percent) was made up of rural roads which accounted for 98,675 miles.[3]

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[1]Infrastructure is a transportation term which refers to the physical attributes of the underlying framework or foundation which facilitates the transport function.

[2]Michigan State University, Division of Research, Graduate School of Business Administration, Michigan Statistical Abstract, East Lansing, Michigan: Michigan State University, 1978.

[3]Ibid.

Nonsurfaced rural road mileage accounted for 16,740 miles.[4] In 1976 rural roads in Michigan had increased slightly to 98,945 miles while non-surfaced rural roads decreased to 15,321 miles.[5] Total road system mileage increased to 118,998 miles by 1976.[6]

The importance to agriculture of the transport system can be seen in the farm output which must be moved to market. In 1977 Michigan farmers harvested and sold 191.3 million bushels of corn, 33.0 million bushels of wheat, 20.9 million bushels of soybeans and 18.7 million bushels of oats.[7] In fruit and vegetable production Michigan growers produced 270,000 tons of apples, 81,000 tons of tart cherries, 33,000 tons of grapes, 14,000 tons of prunes and plums, 12 tons of pears, 41,300 tons of snap beans, 63,500 tons of tomatoes, 9,500 tons of asparagus and 114,000 tons of cucumbers for pickles.[8] Producers of livestock and poultry slaughtered in 1977: 816,636 thousand pounds of liveweight cattle and 22,109 thousand pounds of liveweight calves along with 909,489 thousand pounds of hogs, 34,836 thousand pounds of sheep and lambs and 29,040 thousand pounds of market turkeys.[9] Milk and cream marketed by Michigan dairy farmers in 1977 amounted to 4,761 million pounds.[10] In 1972, the latest figures available, an estimated 96,000 trucks moved 853

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[4]Ibid.

[5]Ibid.

[6]Ibid.

[7]Michigan Department of Agriculture, Michigan Agricultural Statistics, June 1978, Lansing, Michigan, 1978.

[8]Ibid.

[9]Ibid.

[10]Ibid.

million truck miles within Michigan to transport the state's farm product.[11]

The importance of transportation to consumers of agricultural products can be seen in the proportion of the marketing bill which such services comprise. In relation to expenditures for the marketing of farm products, transportation costs represented 8 percent of the total food marketing bill in 1977.[12] As shown in Figure 1-1, transportation was the third most costly component of the food marketing bill behind labor and packaging costs.

1.1 The Problem Setting

The adequacy of rural roads to meet current and projected traffic needs is becoming increasingly important to agriculture and rural communities. Although road quality varies substantially, recent reports indicate that more than three-fifths of all U.S. rural arterial and collector (feeder) roads are identified as deficient. Moreover, one-half of the total U.S. rural feeder mileage is deemed unsuitable for sustained heavy truck traffic. Despite these reports there has been a substantial disinvestment in rural road capital and maintenance programs. When deflated by an index of rural federal aid highway construction costs during the period 1970-1978 total capital and maintenance disbursements for rural roads have been cut by more than 30 percent (see Table 1-1). In the last 10 years construction costs on roads in Michigan have more than doubled. Inflation has significantly increased the cost of road

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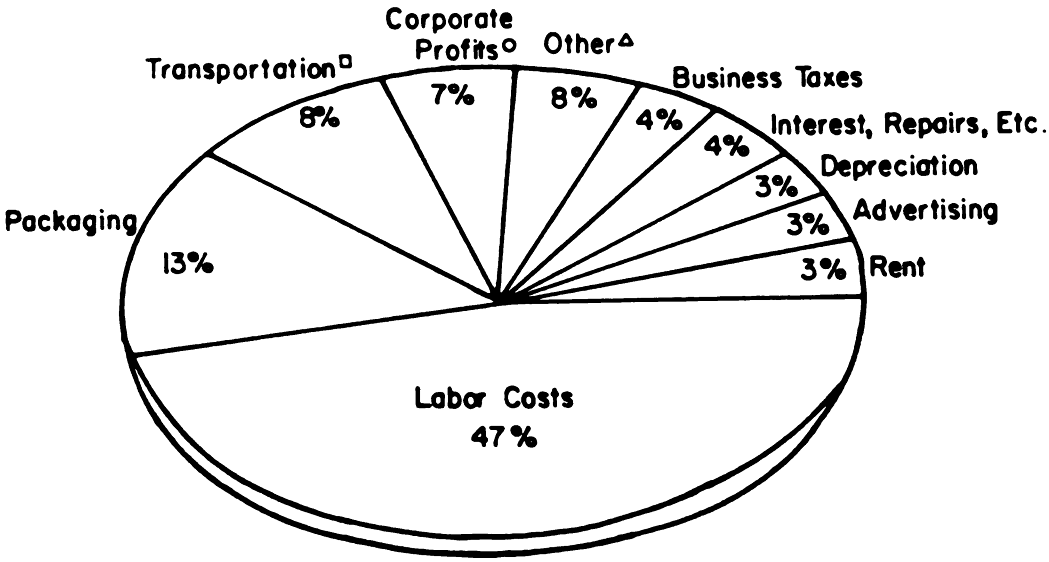
[11] Michigan State University, Division of Research, Graduate School of Business Administration, op. cit.

[12] Michigan Department of Agriculture, op. cit.

COMPONENTS OF BILL FOR MARKETING FARM FOODS, 1977



°Before taxes. □Intercity rail and truck. △Residual includes such costs as utilities, fuel, promotion, local for-hire transportation.

SOURCE: Michigan Department of Agriculture

FIGURE I-1

TABLE 1-1. Capital and Maintenance Disbursements for Rural Roads in the United States*

Year	Capital			Maintenance		
	State	Local	Total	State	Local	Total
			1967 Million $[a]			
1970	5,491	748	6,239	1,436	1,264	2,700
1971	5,227	734	5,961	1,444	1,237	2,681
1972	4,882	743	5,625	1,421	1,219	2,640
1973	4,113	732	4,845	1,452	1,233	2,685
1974	3,417	651	4,068	1,386	1,188	2,574
1975	3,957	717	4,674	1,384	1,301	2,685
1976	3,785	683	4,468	1,365	1,265	2,630
1977	3,263	630	3,893	1,416	1,286	2,702
1978	2,900	545	3,445	1,422	1,220	2,642

*Source: U.S. Department of Agriculture, Agricultural Outlook, AO-42, Washington, D.C., April 1979.

[a]Current dollars were deflated using the price indices for rural federal aid highway construction and maintenance and operation.

maintenance programs. Simultaneously, motor vehicle fund revenues have leveled off and not kept pace with inflation. This has been brought about in part because of better fuel economy and lighter weights in automobiles.

In 1976 the total combined expenditure of Michigan's County Road Commissions reached $267.1 million. Of this amount, $118.5 million was expended for the construction of roads, bridges, roadside parks, etc. Maintenance expenditures for the county rural road system totaled $122.7 million.[13] According to estimates made by the Michigan Department of State Highways and Transportation, construction costs to eliminate all deficient mileage on the county rural road network in the State of Michigan over the next 12 years will be approximately $10 billion.

Of the rural road system currently existing in the State of Michigan, some 36 percent are rated poor and very poor by federal standards. In addition, some 9 percent of the total mileage is rated as fair and noticeably inferior. According to recent legislative studies, by the year 1986 one-third of the State of Michigan's 116,473 miles of paved roads will need to be resurfaced. In addition, it is estimated that 12,382 miles of paved surface roads are too badly worn for resurfacing and must be rebuilt.[14] Recent reports published by the Michigan Department of State Highways and Transportation classified 50,365 miles as inadequate.

The county rural road system makes up about 75 percent of Michigan's total road mileage. County rural road inadequate mileage in the state

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[13]Michigan Department of State Highways and Transportation, <u>26th Annual Progress Report for the County Road Commission, Incorporated Cities and Villages of Michigan</u>, Report No. 162, Lansing, Michigan, 1978.

[14]Norris, Carol, <u>Overview: Transportation Package</u>, Michigan House of Representatives, Office of the Speaker, Lansing, Michigan, 1978.

was placed at 38,011 or 75.5 percent of all inadequate mileage. In addition, 1976 estimates place 3,672 bridges in the category of inadequate. Again, the rural road system accounted for the majority of inadequate bridges at 2,654 structures.[15]

Much of Michigan's rural road and bridge system was developed in the early 1900s to meet the traffic needs at that time. However, the capability of the existing system to accommodate today's increased demands is often inadequate. Many factors have contributed to the present status of the county rural road system in Michigan.

The development of the truck and automobile industry in the 1920s and 1930s created a need to surface many of the county rural roads and replace some of the bridges to sustain the gross weights of trucks up to 6 or 7 tons. During the same period, rapid advances were observed in farm productivity through the use of increased mechanization and high yielding inputs. This increased productivity accelerated the deterioration of county rural roads as produce was trucked to market. A recent study indicates that within the next 20 years an increase of over 50 percent is expected in the quantity of grain requiring commercial transportation services in Michigan.[16]

Farm equipment has become increasingly larger as a result of farmer demand and farm consolidation. Disks and row-crop cultivators are up to 54 feet wide. Even though the equipment can be folded to 18 to 20 feet in width, it will not pass through bridges with design widths of 16 to 18 feet.

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[15] Ibid.

[16] Thompson, Stanley R., "Transportation Needs for Michigan Grain in 1985 and 2000," Michigan Farm Economics, No. 426, July 1978.

Since 1940, Michigan has experienced a 62.1 percent decrease in the total number of farms and 162.9 percent increase in farm size.[17] The increase has brought about the use of substantially larger vehicles. A recent study of rural road and bridge problems in America has indicated it is not uncommon to see tandem-axel trucks with a gross weight of 23 tons using the rural road system.[18] The use of the larger farm vehicles to haul grain longer distances has been a competitive response to the availability of low-cost unit trains that are often available at more distant terminal elevators.

Recent and potential rail line abandonment decisions are placing additional stress on Michigan's rural road system. The United States Railway Association (USRA) Final System Plan for restructuring the bankrupt railroads in the Northeast and Midwest lists more than 1,300 miles of railroad in the State of Michigan that were left out of the Final System Plan and ConRail. In addition, some 500 miles of railway are or will soon be under petition for abandonment. If these 1,800 miles of railway were abandoned, a 15 county area of Michigan would be without rail service and many other rural communities would have little rail service. More than half the grain elevators in Michigan are located on light-density lines under abandonment pressure. Abandonment of these lines would require a major adjustment not only in the grain marketing system, but also in the distribution of fertilizer and building supplies. Because of the high degree of substitutability between rail and trucks, rail abandonment will place a substantial added stress on the remainder

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[17] Michigan State University, Division of Research, Graduate School of Business Administration, op. cit.

[18] U.S. Department of Agriculture, National Extension Transportation Task Force, The Local Rural Road and Bridge Problem and Alternative Solutions, C. Phillip Baumel.

of the state's transportation system, especially the rural road system.

Stress on the existing Michigan county rural roads has come about as a result of increasing pressure from an expanding population. The growth of cities and villages have served to increase the traffic flow in rural areas. Interestingly, between 1950 and 1970 rural population in the United States declined a little over 1 percent while Michigan's grew at over 24 percent.[19] Estimated 1977 rural population in Michigan stands at 2,970,817, an increase of approximately 60 percent since 1950.[20]

Continuation of the above trends can result in serious implications for Michigan agriculture and the rural community. As we enter an unprecedented period of rural transportation adjustments, both private and public decision makers, particularly at the state and local levels, are seeking analytical assistance. Hopefully, the results of this research will enable more effective planning of Michigan's total transportation system while giving proper recognition to the importance of the rural road component.

1.2 Research Objectives

The primary objective of this research is to investigate a localized rural transportation system within the State of Michigan in order to assess the economic impact of improving or developing the rural road

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[19] U.S. Department of Commerce, Bureau of the Census, U.S. Census of Population: 1970, Number of Inhabitants, Michigan, Final Report PC(1)-A-24, Washington, D.C.: U.S. Government Printing Office, 1971, Table 9.

[20] U.S. Department of Commerce, Bureau of the Census, Current Population Report, Farm Population, Farm Population of the United States: 1977, Advanced Report Series, P 27, No. 50, Washington, D.C.: U.S. Government Printing Office, March 1978.

infrastructure. Previous research efforts such as Riorden[21] have suggested that transportation costs of hauling grain is a function of the road surface traveled. For a given transport distance the cost of hauling grain is lower on roads with paved surfaces than on earthen or gravel roads. It is the aim of the research to test the hypothesis that improving the rural road network will have a significant economic impact upon agriculture. In evaluating improvements and changes in the rural transportation system attention will be focused upon how it will affect (a) the commodity flow pattern of grains; and (b) aggregate transportation assembly costs of hauling grain.

In order to evaluate the major premise of this research, six specific facilitative objectives must be accomplished. To this end the following is completed:

(1) An inventory and description of the existing rural transportation network in Lenawee County.

(2) A description of the grain assembly marketing system within the study region.

(3) The development of a theoretical framework within which to study the rural transportation network.

(4) The estimation of current demand and line-haul costs for grain transportation by production centroid and grain elevator.

(5) The implementation of an appropriate programming algorithm to empirically rationalize[22] the rural road system.

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[21] Riorden, E.B., "Spatial Competition and Division of Grain Receipts Between Country Elevators," M.S. Thesis, University of Manitoba, 1965.

[22] Rationalization as it is used here is meant to theoretically describe the road and highway system and the grain transport movement upon it.

(6) An evaluation of the economic effects of alternative rural assembly logistical systems on commodity flows and transport efficiency.

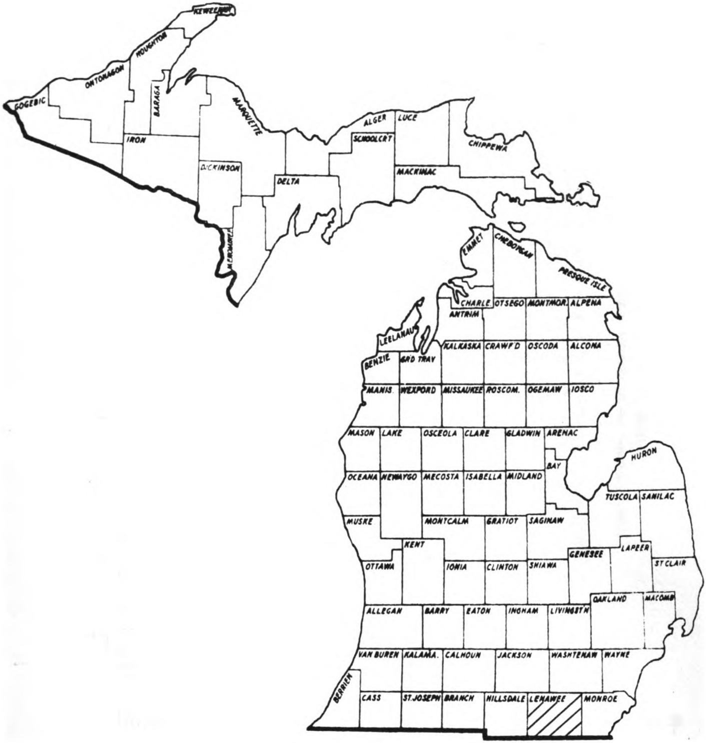
It is the intention of this research to contribute to a better understanding of the rural transportation component of grain marketing in agriculture. It is hoped this research will provide insights for more efficient rural transport planning and utilization.

1.3 The Study Area

The region which serves as the study area in this research is Lenawee County. Lenawee is a rural county located in southeastern Michigan and is bordered to the south by the State of Ohio, to the west by Hillsdale County, to the north by Jackson and Washtenaw Counties and to the east by Monroe County (see Figure 1-2). Lenawee County, with its county seat located at Adrian, encompasses 753 square miles of area (see Figure 1-3) and has an estimated 1977 population of 85,400.

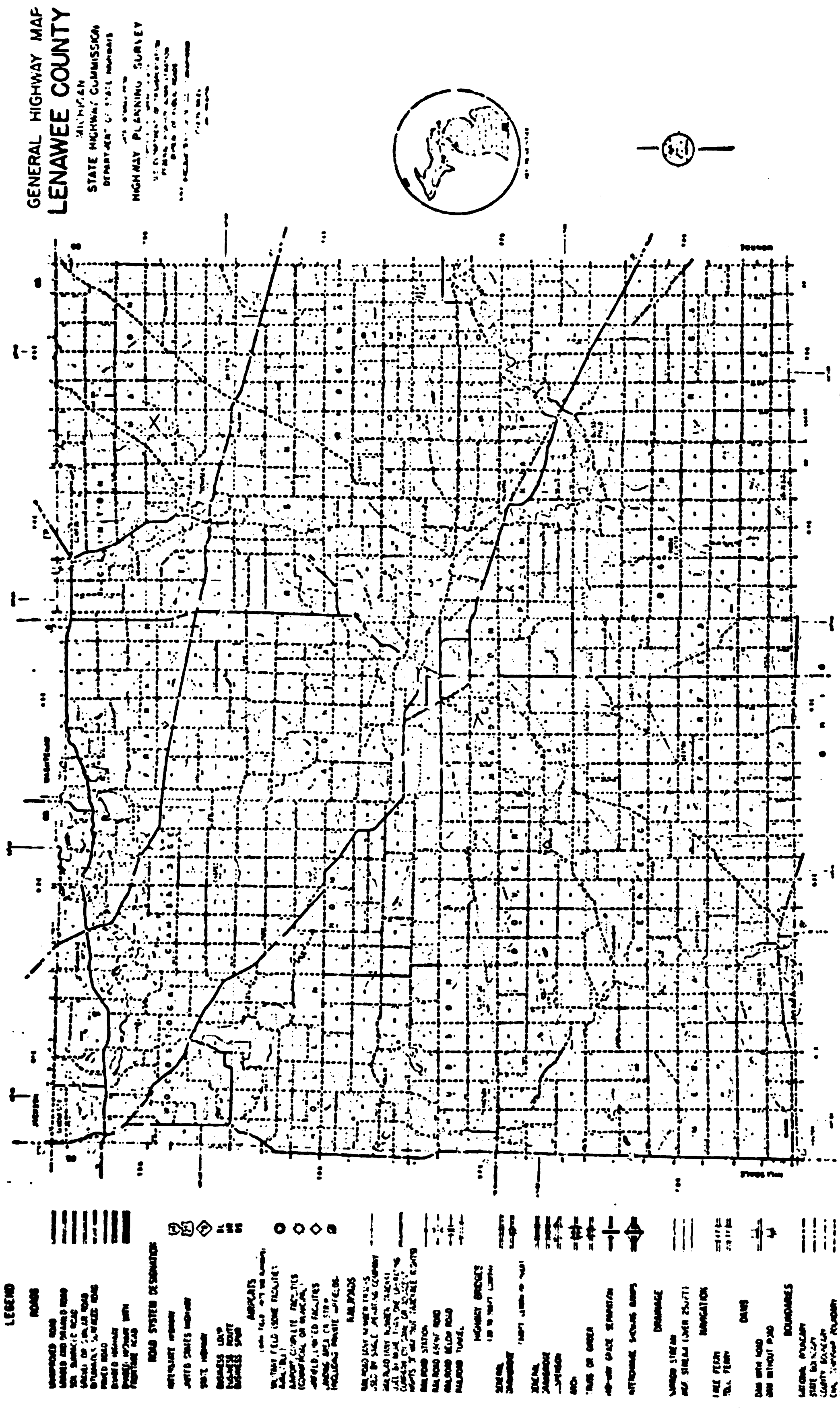
Economically, Lenawee County was chosen for study because of its high grain production, semideveloped rural road system and potential rail line abandonment. Lenawee County ranked first out of the state's 83 counties in 1977 for the production of corn with 12.3 million bushels, first in wheat production with 2.2 million bushels, first in soybean production with 3.7 million bushels and fifth in the production of oats with 0.7 million bushels. In addition, the county is served by five country elevators.

According to the Michigan Railroad Plan, 26.4 miles of rail lines in Lenawee County are subject to pending abandonment application. The Wauseon, Ohio to Tecumseh segment of the Detroit, Toledo and Ironton



Michigan County Boundaries Map

FIGURE 1-2



General Highway Map of Lenawee County

FIGURE 1-3

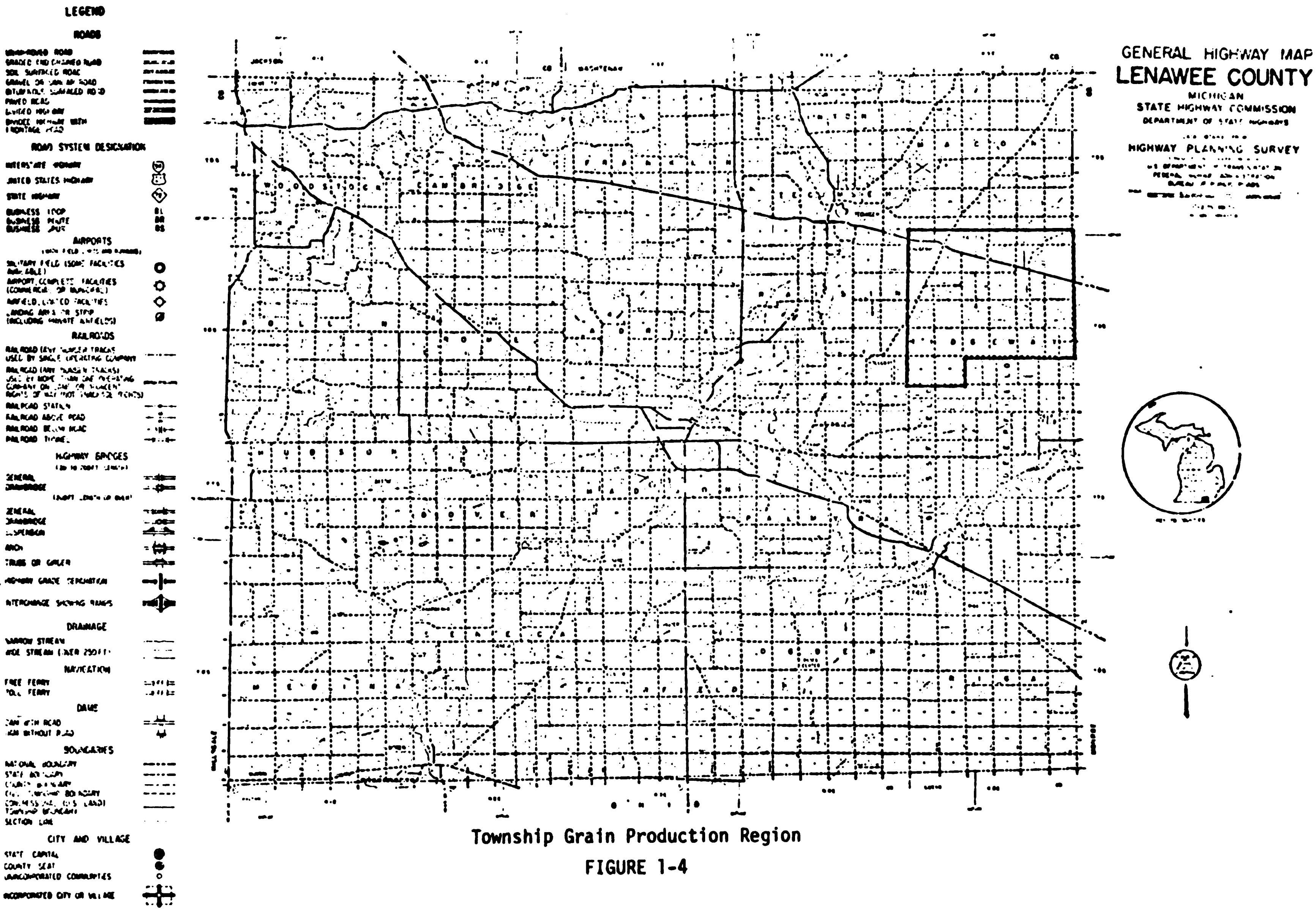
Railroad, serving Adrian and Tecumseh, filed for abandonment in June 1975.

Technical rationale, in addition to economic reasons, existed for choosing this particular county to investigate. Among such factors included geographical configuration and highway planning consideration. The geographical and geological configuration of the land in the study region simplified the framework for empirically rationalizing the county transportation network. In addition, officials of the Michigan Department of State Highways and Transportation expressed an interest in obtaining information for planning purposes within a group of six counties comprising two of the state's 14 highway planning districts. Lenawee County was one of these six. By choosing this county it is hoped the research will provide a more integrated and practical result which can be utilized by those officials engaged in and responsible for highway planning.

In order to investigate changes in commodity flows and transport costs to agricultural pursuits in grain production and marketing, a smaller production area within Lenawee County was studied. The production area chosen was Ridgeway Township (see Figure 1-4), a major producer of grain within Lenawee County. Ridgeway Township is a fertile region of the county, encompassing approximately 26 square miles of land. The road system, being semideveloped, is representative of that found in the county. Since the production region is a subset of the study area, distortions in commodity flows were minimized.

1.4 Data Sources

Data which is utilized in this research was obtained or generated from various sources. Both primary and secondary information were made



Township Grain Production Region

FIGURE 1-4

use of in this research effort. The major informational needs of this study were satisfied by various governmental units on the federal, state and local levels. In addition to governmental sources, the expertise of faculty members and extension personnel at Michigan State University provided invaluable support in the form of suggestions and facts. A limited amount of the research data was obtained through surveys.

1.4.1 Descriptive Data

Empirical data that was used to describe the existing transportation network within the State of Michigan and the study area, Lenawee County, came primarily from the Michigan Department of State Highways and Transportation. This information was the result of integrating two data files, the Michigan Transportation Modeling System Network File and the Michigan Highway Needs File, into one coherent file for the study area. Verification and additional information was sought from various transportation studies and from officials of the County Road Association of Michigan. Descriptive data relating to grain production within the study area was secured from documents provided by the United States Department of Agriculture and the Michigan Department of Agriculture. Data relating to grain elevator costs, capacity and operations were obtained through a telephone survey interview with each grain elevator operator in Lenawee County and from information provided by the Michigan Grain and Agri-Dealers Association.

Data pertaining to line-haul transport costs as a function of average operating speed was derived from published records of the Interstate Commerce Commission, Bureau of Accounts. Utilizing this data and information from the Michigan Department of State Highways and Transportation, line-haul costs relating to road surface and type were generated.

1.4.2 Analytical Data

Data relating to the theoretical and conceptual framework of this research is secured from many sources. In developing the analytical data of this study great reliance was placed upon research by scholars in agricultural economics, engineering, economics and geography. A transportation model algorithm available and operational at the Michigan State University Computer Center was utilized in the analytical procedure.

1.5 Literature Review

Published research results investigating the impacts of rural road development or deterioration on the agricultural community are scarce. The various research efforts which have been undertaken can be classified as either empirical or methodological. Empirical research studies are designed to address a specific problem in relation to rural roads. On the other hand, the objective of the methodological research studies is to develop or demonstrate the use of modeling techniques for use on applied problems such as those addressed in this thesis.

Highway studies have consistently concluded that few rural roads have a benefit/cost ratio which would exceed a value of 1. In 1973 Smith, Wilkinson and Anschel[23] concluded that,

> In some of the more densely populated neighborhoods with relatively stable population, a strong case could be made for investments in road improvement to bring them up to all-weather standard. However, in thinly populated communities, or ones in which rapid declines can be expected, such expenditures are not justified on economic grounds.

This study intended to support the findings of the Coordinator of

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[23] Smith, Eldon D., J. Keith Wilkinson and Kurt R. Anschel, "Economic Costs and Benefits of Rural Road Improvement in the Eastern Kentucky Coal Fields," Agricultural Experiment Station Research Report 18, University of Kentucky, October 1973, p. 24.

Transportation[24] and the National Resources Planning Board (NRPB).[25] The NRPB document concluded that,

> Of the vast highway mileage in the United States, many thousands of miles of little traveled routes (rural roads) have no legitimate claim for improvement with public funds.

Other empirical studies have been designed to measure specific impacts upon the agricultural community. The most common measure of rural road economic impact is to look at the change in the value of rural property as improved roads are provided to link typical locations not served by paved roads. Two such studies which have demonstrated a positive relationship between rural property values and rural road development have been made by Mordecai Ezekiel[26] and William L. Garrison.[27]

Most methodological studies have demonstrated the usefulness of linear programming techniques as tools to investigate rural road problems. Linear programming has been used to solve such problems as determining the optimal bus routing in rural areas and establishing the optimal logging routes to be used in the National Forests by the U.S. Forest Service. Economic rationale is generally the foundation of most linear programming models. Clyde Weller[28] has pointed out the need for

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[24] U.S. Congress, House, "Fourth Report of the Federal Coordinator of Transportation on Transportation Legislation," House Miscellaneous Documents, 74th Congress, 2nd Sess., 1936.

[25] National Resources Planning Board, Transportation and National Policy, May 1942, p. 399.

[26] Ezekiel, Mordecai, Factors Affecting Farmers' Earnings in Southeastern Pennsylvania, U.S. Department of Agriculture, Bulletin 1400, 1926.

[27] Garrison, William L., Allocation of Road and Street Costs - The Benefits of Rural Roads to Rural Property, Washington State Council for Highway Research, June 1956.

[28] Weller, Clyde G., "The Economics of Rural Road Systems," Proceedings of the National Symposium on Transportation for Agriculture and Rural America, New Orleans, Louisiana, November 15-17, 1976, p. 189.

other considerations beyond economic efficiency. Weller has stated,

> The economics of road systems is complex, but not impossible to compute. The optimization of alternate routes or alternate systems must be based on the best blend of the optimizing rationales: (1) efficiency, (2) safety, (3) environmental, and (4) political.

The use of linear programming to solve transportation problems has been demonstrated mathematically by Snodgrass and French.[29] A modification of the transportation linear programming technique was developed by C. Phillip Baumel.[30] This methodological procedure is a transshipment plant location model which is designed to determine the number, size and location of plants. This type of model may be very useful in addressing such problems in rural road development as the determination of the location and number of miles of rural roads to optimize a given system.

Although this research has identified previous studies relating to rural roads, there currently exists a void in the research literature on the role, importance and economic impact of rural roads on the agricultural community.

1.6 Organizational Framework

This study has been organized into seven major chapters. Each chapter has then been further broken down into various topical components.

Chapter I serves as an introduction to the study and is designed to outline the basic research hypothesis and objectives, problems and

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[29] Snodgrass, Milton M. and Charles E. French, "Simplified Presentation of 'Transportation-Problem Procedure' in Linear Programming," Journal of Farm Economics, Vol. 39, No. 1, February 1957, pp. 40-51.

[30] Ladd, George W. and Dennis R. Lifferth, "An Analysis of Alternative Grain Distribution Systems," American Journal of Agricultural Economics, Vol. 57, No. 3, August 1975, pp. 420-430.

geographical area of study. It is designed to give a brief description of the Michigan rural transport system and the problems facing rural Michigan which impact upon grain commodity movements and costs. This chapter briefly profiles the geographic study area and its important demographic and economic characteristics. It also serves the purpose of identifying the researchable hypothesis of the study and the procedure for testing such supposition. Finally, this chapter explores the various major sources of data utilized in the research study.

Chapter II is designed to acquaint the reader with the existing rural transportation infrastructure within the study area. To accomplish this end the chapter identifies various physical, economic and service characteristics of the grain transport system as it exists in Lenawee County.

Chapter III provides a descriptive analysis of the grain assembly marketing system as it exists within the study region. This chapter characterizes the grain production in Lenawee County, including size and distribution of production, value of product, farm size, etc. It identifies such factors as who undertakes the assembly function and how it is made operational. Finally, this section identifies both intermediate and terminal grain elevators with respect to location, capacity, number, size, operations, etc.

Chapter IV presents the theoretical considerations and research methodological procedures employed in the analysis of the research problem investigated. The various topical components discussed in this chapter include the economic model, the mathematical model and the computer model which were applied in helping to solve this research problem. This chapter outlines in detail the analytical procedures used in making the various models workable for the study region, including a discussion of the alternative transportation scenarios investigated and the feasibility assumptions employed.

Chapter V is a discussion of the techniques applied in deriving estimations of regional grain supplies, grain assembly costs and rural road development and maintenance costs. This chapter is designed to provide the basic parameter values which were incorporated into the methodological procedures outlined in Chapter IV.

Chapter VI is a presentation of the empirical results of the research effort. It is intended to convey the values which the optimization models developed in Chapter IV regard as relevant to the analysis of the study.

Chapter VII in this research study is the economic and policy analysis of the results presented in the previous portions of this investigation. It discusses the impact of rural road development and their implications for grain producers and elevator operators. The chapter also serves to summarize the study and point out areas of further needed research.

1.7 Summary

Recent economic and financial trends relating to increased productivity, rail line abandonment pressures, declining real expenditures for rural road capital and maintenance programs and increasing pressure from an expanding population have combined to contribute to the deterioration of Michigan's rural road infrastructure. It is the same road network which must facilitate the movement to market of Michigan's expanding agricultural production. A continuation of these trends could have serious implications for Michigan agriculture and the rural community.

This study is an attempt to empirically analyze some of these implications and to investigate the economic impact of further developing the rural road system. As such, it is designed to fill a void in the transportation/marketing research literature which exists in the analysis of rural road development and/or deterioration impacts to agriculture. To achieve this, the study is designed to test the hypothesis that the improvement of the rural road network will result in a significant economic impact upon agriculture. In evaluating improvements and changes in the rural transportation system attention was focused upon how it affects (a) the commodity flow pattern of grain; and (b) aggregate transportation assembly costs of hauling grain.

Lenawee County was chosen as the study area for this investigation based upon both economic and technical rationale such as its high grain production, semideveloped rural road system and potential rail line abandonment. Using an optimization model, the study investigates the economic consequences of grain movements in this study area between producers and the five local intermediate country elevators and the terminal elevator facilities located in the Toledo, Ohio area.

CHAPTER II

THE EXISTING RURAL TRANSPORTATION NETWORK IN LENAWEE COUNTY

The purpose of this chapter is to acquaint the reader with the rural transportation network as it presently exists in Lenawee County. In presenting the inherent characteristics of the transportation system found within the study area of this research it is intended to provide a better understanding of the research problem under investigation. To accomplish that end, this chapter is subdivided into three principal characteristic categories. These major divisions are the physical characteristics, service characteristics and economic characteristics of the transport infrastructure. To secure the needed information for this chapter, many sources were utilized. Paramount among informational sources was access to computer files located within the Michigan Department of State Highways and Transportation. Other sources included reports, publications and conversations with officials of the United States Department of Transportation and the Lenawee County Rural Road Commission.

2.1 Physical Characteristics

As was previously pointed out in the Introduction to this research study, the State of Michigan's total road infrastructure is comprised of approximately 119,000 miles of road. Lenawee County is crisscrossed by 1,642 of these miles or 1.4 percent of the total road and highway infrastructure in the state. The road system in Lenawee County was primarily surveyed and laid down at the turn of this century. Because of the influence of the grid system of surveying,[1] Lenawee County's rural road network is laid out in a pattern of squares, each encompassing approximately 1 square mile of area. This pattern can be seen on the following page in the computer map of the complete transportation system located in Lenawee County.

2.1.1 Legal Systems

The road system in Lenawee County is categorized into five major classifications called legal systems. Legal systems primarily distinguish road usage and jurisdictional responsibilities. Legal system 1 delineates the state trunk lines which include state highways, U.S. highways and interstate highways. The major north-south highways in Lenawee County are U.S. 127 and M-156 and M-52. Running in an east-west direction through the county are U.S. 12, U.S. 223, M-34 and M-50. Legal systems 2 and 3 are the county primary and local roads, respectively. The great majority of Lenawee County's total road network is comprised of these county roads. There exists 1,350 miles of county roadway in the study area of which 896 miles are county local roads. Legal systems 4 and 5 identify the street networks within incorporated cities and villages. Legal system 4, having the smallest amount of mileage at 61 miles, is the classification used to categorize all major streets within the jurisdiction of incorporated areas. Legal system 5 is the local streets within the same jurisdiction.

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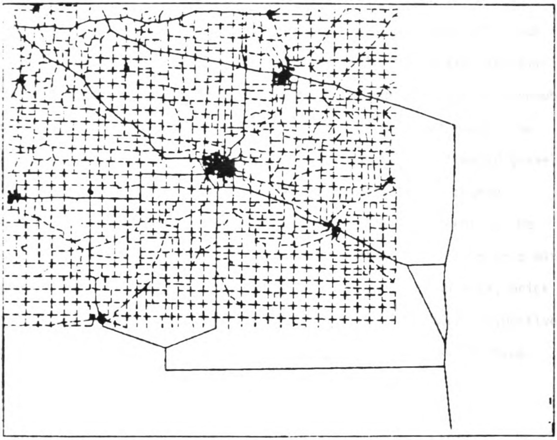
[1]The grid system is a method of surveying which in its simplest form is the establishment of boundaries based upon a progression of rectangles usually in the shape of squares.

Computerized Road and Highway Map
for Lenawee County

FIGURE 2-1



2.1.2 Surface Type

There are six surface type structures of roads located in Lenawee County (see Table 2-1). Surface type structures include (a) graded and drained earth; (b) gravel and similar; (c) bituminous surface treated gravel; (d) mixed bituminous surface on gravel of 1 inch or more; (e) mixed bituminous surface on concrete or brick or black base of 1 inch or more; and (f) concrete. As indicated in Table 2-1, gravel and similar material surfaced roads account for most of the surface type in Lenawee County. This surfacing material is found on 709 miles of road. The second most prevalent surface type is bituminous surface treated gravel.[2] This type of surface makes up 442 miles of roadway in the county. Together, these two road surface types account for 70 percent of the total road mileage in Lenawee County. Road surface consisting of a mixed bituminous exterior of 1 inch or more on gravel and on concrete, brick or black base constitute 295 miles and 142 miles of roadway, respectively. Concrete surfaced roads cover 43 miles and graded and drained roads account for 11 miles.

2.1.3 Surface Deterioration Conditions

The road and highway infrastructure within the State of Michigan is surveyed and rated by state and county engineers according to surface deterioration conditions. There exists five such deterioration factors or categories--excellent, good, fair, poor and very poor. Table 2-2 indicates the surface deterioration conditions by existing road type for the study region of this research effort. A rating of excellent is given

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[2]A bituminous surface treated gravel is a gravel road which has been sprayed with an oil-tar mixture.

TABLE 2-1. Road Surface Type by Road Type in Lenawee County, Michigan, 1977*

Road Type	Road Surface Type: Graded and Drained Earth	Gravel and Similar	Bituminous Surface Treated Gravel	Mixed Bituminous Surface on Gravel	Mixed Bituminous Surface on Brick, Concrete or Black Base	Concrete	Total
				(Miles)			
State Trunk Lines	0	0	0	22	78	41	141
County Primary	0	40	231	134	49	0	454
County Local	11	661	183	37	4	0	896
City and Village Major	0	0	4	46	10	1	61
City and Village Local	0	8	24	56	1	1	90
County Total	11	709	442	295	142	43	1,642

*Source: Michigan Department of State Highways and Transportation, Planning Division (taken from engineering studies of Michigan's highway needs).

TABLE 2-2. Surface Deterioration Condition by Road Type in Lenawee County, Michigan, 1977*

Road Type	Deterioration Factor				
	Excellent	Good	Fair	Poor	Very Poor
			(Miles)		
State Trunk Line	7	30	75	20	9
County Primary	68	166	95	83	42
County Local	26	408	246	169	47
City and Village Major	14	18	15	11	3
City and Village Local	15	13	19	19	24
County Total	130	635	450	302	125

*Source: Michigan Department of State Highways and Transportation, Planning Division (taken from engineering studies of Michigan's highway needs).

when there appears no visible or apparent signs of surface deterioration. An excellent rating is given to 130 miles of Lenawee County's road and highway network. These 130 miles of roads make up approximately 8 percent of the existing infrastructure. When a road is deemed in good condition it implies an average maintenance requirement with surface deterioration of 5 percent or less of the roadway being evaluated. The majority of roads in Lenawee County are classified as good. This classification accounts for over 38 percent of the road and highway system and encompasses 635 miles. A fair rating is given on roads with up to 25 percent deterioration. These roads may require an above average maintenance program. Twenty-seven percent or 450 miles of the county's roadway is termed fair. Three hundred and two miles of road system is classified as poor. These roads require extensive maintenance with possible resurfacing. Over 25 percent of the length of the road segment being evaluated is deteriorated to warrant a poor rating. A very poor rating indicates that the road is beyond normal maintenance capabilities and that extreme deterioration has occurred. Lenawee County has 125 miles or about 8 percent of the road system defined as very poor.

The major portion of state trunk lines within Lenawee County are rated as fair. Over 50 percent of the state trunk line mileage falls within this surface deterioration classification. Twenty percent of the state trunk lines are rated poor or very poor with 20 miles and 9 miles, respectively, being so classified. Thirty-seven miles of state trunk line are ranked as either excellent or good.

The county primary system is judged to be mostly comprised of excellent to fair surfaced roads. These classifications comprise 72.5 percent of the county primary network. The majority of these roads at

166 miles are found to be in good condition. Sixty-eight miles are excellent and 95 miles are fair. The remaining 125 miles of rural primary roads are in poor or very poor condition.

The county local roads are similar to the county primary system. Over 75 percent of the county local roads are classified as excellent to fair. Some 408 miles are deemed in good condition with 26 miles rated excellent and 246 miles rated fair. However, almost 170 miles are in poor condition and 47 miles are rated very poor.

The city and village major and local streets combined are almost evenly divided among the five classes of road surfaces. The city and village major street system has 14 miles of excellent surfaced streets, 18 miles of good streets, 15 miles of fair streets, 11 miles of poor streets and 3 miles of very poor streets. The local city and village street network is comprised of 15 miles of excellent pavement, 13 miles of good surface, 19 miles of each of fair and poor roads and 24 miles of very poor streets.

2.1.4 Base Condition

Besides surface deterioration factors, another important determinant of the overall quality of the road and highway infrastructure is the condition of the base. The base is the material foundation over which the roadway is constructed. The stage of deterioration of the base is evaluated according to two criteria, the drainage qualities of the material making up the road foundation and its ability to sustain traffic flow. As with the surface deterioration rating, the base deterioration as assigned by state and local engineers fall within one of five evaluation categories. These categories or ratings are excellent, good, fair, poor and very poor. An excellent rating indicates no apparent or visible deterioration of the base. A good rating usually implies normal maintenance requirements and means less than 5 percent of the length of the base is deteriorated. A fair rating for a roadway foundation may indicate the need for above average maintenance as up to 25 percent of the base length is deteriorated. Excessive maintenance is required on a base deterioration rating of poor. This indicates deterioration of more than 25 percent of the road support length. When extreme deterioration of the road substructure has occurred and it is beyond maintenance repair, the base is rated very poor. Table 2-3 depicts the road base deterioration conditions of each type of road in Lenawee County.

As can be observed from Table 2-3, the largest portion of the road foundation in Lenawee County is good. Over 40 percent or 695 miles of roadway base is rated good. Almost one-quarter of the foundation is in poor or very poor condition. Two hundred and forty-one miles of base is poor and 156 miles is very poor. The county has 445 miles of fair rated base and 105 miles rated as excellent.

The largest component of the state trunk line base is rated as being in fair condition. This fair base mileage is placed at 52 miles. The second largest component of the foundation has been determined to be in very poor condition. Almost 25 percent of the state trunk line is rated very poor. Fifteen miles of state trunk line base is in excellent condition with 31 miles rated good and 10 as poor.

Three-fourths of the county primary roadway base is rated as fair or better. Most of the base is classified as good, accounting for 212 miles. Forty-eight miles show no apparent deterioration while 82 miles are deemed in fair condition. Of the remaining 112 miles, according to

TABLE 2-3. Roadway Base Deterioration Condition by Road Type in Lenawee County, Michigan, 1977*

Road Type	Deterioration Factor				
	Excellent	Good	Fair	Poor	Very Poor
			(Miles)		
State Trunk Line	15	31	52	10	33
County Primary	48	212	82	62	50
County Local	26	409	268	147	46
City and Village Major	12	20	18	9	2
City and Village Local	4	23	25	13	25
County Total	105	695	445	241	156

*Source: Michigan Department of State Highways and Transportation, Planning Division (taken from engineering studies of Michigan's highway needs).

engineering standards, 62 miles are rated poor and 50 miles are defined as very poor.

The county local system's base is generally in good condition. Over 45 percent of the county local roadway foundation is rated good. Another 268 miles is determined to be in fair condition. At the extremes, 26 miles of base are found in excellent condition while 46 miles are deemed very poor. The remaining 147 miles are classified as being in poor condition.

Street bases within incorporated areas are generally in good to fair condition. Sixty-two percent of the major city and village street foundation is within these ratings with 53 percent of the local roadway base falling within these categories of engineering standards. The city and village major street base is comprised of 12 miles of excellent foundation, 20 miles of good, 18 miles of fair, 9 miles of poor and 2 miles of very poor. The city and village local roadway base constitutes 4 miles of excellent substructure, 23 miles of good, 25 miles of fair, 13 miles of poor and 25 miles of very poor.

2.1.5 Traffic Lanes

As indicated in Table 2-4, Lenawee County has one, two, three and four lane roads and highways. The vast majority of roadway in the county is two lane, where a traffic lane is defined to mean a road surface with a minimum width of 9 feet measured under rush hour conditions. All but 49 miles of thoroughfare in the county are designed for two lane traffic. The entire county primary road system consists of two lane traffic flow, while 99.4 percent of the county local rural roads are engineered to this standard. Six miles of the road system in Lenawee County are designed

TABLE 2-4. Number of Miles of Traffic Lanes by Road Type in Lenawee County, Michigan, 1977*

Road Type	Number of Traffic Lanes 1	2	3	4	Total
		(Miles)			
State Trunk Line	0	138	0	3	141
County Primary	0	455	0	0	455
County Local	5	891	0	0	896
City and Village Major	0	42	4	14	60
City and Village Local	1	67	20	2	90
County Total	6	1,593	24	19	1,642

*Source: Michigan Department of State Highways and Transportation, Planning Division (taken from engineering studies of Michigan's highway needs).

for single lane traffic flow, 24 miles have three lane capacity and 19 miles can handle four lanes of traffic.

2.1.6 Surface Width

The actual surface width varies substantially ranging from 9 feet to over 26 feet. Over 45 percent of the road network is less than 20 feet in width. The county primary and local roads account for most of this road width class with 712 miles. No county road exceeds a surface width of 26 feet. The majority of the state trunk lines are engineered to width standards of between 20 and 26 feet. Out of the 141 miles of state trunk line, 125 miles fall within this classification. The county incorporated areas contain most of the road network with widths exceeding 26 feet. Seventy-three miles of this roadway exceed the 26 feet surface width.

2.1.7 Traffic Sustaining Ability

All roads in Lenawee County with the exception of 4 miles of county local roads are classified as being able to sustain traffic for at least 6 months out of the year. All season truck routes are defined as those segments of the roadway infrastructure which are capable of supporting the maximum legal load permissible. The maximum legal load allowed in the State of Michigan is an 18,000 pound single-axle load or a 32,000 pound tandem-axle load and no overall gross combination. Only 65 miles of county local and primary roads within Lenawee County can be designated as all season truck routes. The remaining 1,285 miles of county roads are not engineered to handle traffic approaching the legal load limit. Over 85 percent of the state trunk line in the county and all the major streets within incorporated areas can handle maximum legal loads. Over

95 percent of the local streets in incorporated areas are structurally unable to carry maximum legal loads.

2.1.8 Shoulder Type

Shoulder types found on the Lenawee County road and highway infrastructure consist of three standards. Paved shoulders consist of concrete or bituminous material, stabilized shoulders are made of a mixture of soil, gravel, broken stone or seal coat and earth shoulders are comprised of soil, soil with turf or oiled soil. Only 5 miles of road have paved shoulders. These shoulder types are found on the state trunk line. Approximately 60 percent of the infrastructure shoulders are of the stabilized type. The majority of the state trunk line and county primary roads have stabilized shoulders. Stabilized shoulders account for 40.5 percent of the county local roads, approximately 50 percent of the cities' and villages' major streets and approximately 30 percent of local streets within incorporated areas. The remaining approximate 40 percent of the total county road system has earthen shoulders.

2.1.9 Shoulder Conditions

Shoulder conditions are rated as good, fair or poor. Shoulders which show no visible or apparent signs of a deterioration of the surface are rated as good. A fair rating is given to shoulders with a deterioration of 25 percent or less of the surface length being evaluated. This rating may indicate an above average maintenance requirement for such shoulders. When shoulders show an extreme degree of deterioration and are beyond maintenance capabilities it is deemed to be in poor condition. Over 55 percent of total road network shoulders in Lenawee County are rated as fair or poor. Of the 141 miles of shoulder located along the state trunk line, 123 miles are rated as good, 6 miles as fair and 12 miles as poor. Half of the county primary system has shoulders in good condition with 154 miles deemed fair and 72 miles as poor. Over 65 percent of the county local roads have shoulders rated as fair or poor. The good shoulder mileage accounted for 288 miles while 283 miles were rated as fair and 266 miles as poor. The remaining 59 miles of county local road shoulders were not recorded. The incorporated areas' major street shoulders were rated approximately 50 percent good and 25 percent fair and poor each. The local city and village street shoulders showed a poor rating for 47 percent of the mileage, 20 percent was rated as fair and 33 percent was rated good.

2.1.10 Deficient Mileage

Considering all factors previously discussed such as surface type, surface deterioration, shoulder type, etc., and accounting for present and future traffic volumes, average weather conditions, etc., overall deficient[3] mileage on the road and highway network can be obtained. Table 2-5 indicates the deficient road mileage within Lenawee County by increments of 5 years, assuming no maintenance program. In 1977 there existed 459 miles of deficient mileage on the county road system. This represented almost 28 percent of the entire road mileage in Lenawee County. Over 80 percent of this deficient road mileage occurred on the county primary and county local road network. Two hundred and eight miles of county local roads were insufficient for sustaining originally

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[3]A deficient road being a highway or road structure which is not capable of carrying the traffic volume or type that it was designed for or the current transport demands placed upon it.

TABLE 2-5. Deficient Road Mileage by Year and Road Type in Lenawee County, Michigan*

Road Type	Additional Miles of Roadway Becoming Deficient in 1977	1982	1987	1992	1997	2002
State Trunk Line	14	27	27	7	21	46
County Primary	165	64	129	23	9	65
County Local	208	249	246	53	121	18
City and Village Major	20	15	14	2	3	7
City and Village Local	52	17	6	7	6	3
County Total	459	372	422	92	160	139

*Source: Michigan Department of State Highways and Transportation, Planning Division (taken from engineering studies of Michigan's highway needs).

designated traffic flows and 165 miles of county primary roads were inadequate. Located on the state trunk lines were 14 miles of inadequate road mileage in 1977. The incorporated areas of Lenawee County had 72 miles of inadequate streets, 20 miles of major streets and 52 miles of local streets.

As indicated in Table 2-5, within a 10 year span of time it is estimated that an additional 800 miles of roadway will deteriorate sufficiently to warrant being inadequate if adequate maintenance programs are curtailed. The majority of this deterioration will occur on the local roads. Failure to adequately maintain all roads and highways within Lenawee County will result in all roads becoming deficient by the year 2002.

2.2 Service Characteristics

The purpose of this section is to provide information relating to the service characteristics of the road and highway transportation system in Lenawee County. The service characteristics of the transport network pertain to those factors which influence the amount and quality utilization of the system.

The road and highway network in Lenawee County is utilized to facilitate the flow of both goods and people. It is estimated that approximately 10 percent of the traffic flow on the state trunk lines is truck traffic. The remaining 90 percent is passenger traffic. On the rural county network, approximately 5 percent of the traffic flow is truck and 95 percent passenger. Almost all of the truck traffic on the rural county system is agriculture oriented. The major commodity outflow from Lenawee County is agricultural products.

Various types of vehicles utilize the transportation system of Lenawee County. These vehicles range from motorcycles to the large double trailer truck rigs. The most frequent seen vehicle on the road and highway network is the passenger automobile. In 1977 Lenawee County had 44,787 passenger vehicles registered out of a total vehicle registration of 71,800. The remaining vehicle registration was distributed among commercial (14,143), trailer (9,666) and motorcycle (3,204).

Based upon experience and studies done by the Michigan Department of State Highways and Transportation, average travel speeds in Lenawee County were found to range from 10 mph to 40 mph, depending upon traffic congestion and road surface. Table 2-6 indicates the average travel speed by road surface in Lenawee County. These travel speeds reflect the travel time including the stop and go characteristics on the county road and highway network. As can be observed from Table 2-6, as road surface improves, the average travel speed increases. The lowest travel speeds are found on unimproved earthen roads and on graded and drained earth roads. Both of these surface types allows for an average speed of 10 mph. When gravel or similar material is incorporated into the road system, average travel speed is increased to 20 mph. Placing a tar-oil coating over the gravel or similar material roadbed brings the average mph to 30. If a bituminous surface of 1 inch or more is constructed, the travel speed is increased to 35 mph. A concrete road structure allows for the fastest vehicle movement at an average speed of 40 mph.

On an average day, almost 1.8 million vehicle miles are traveled upon the existing road and highway infrastructure in Lenawee County. Table 2-7 depicts the average daily vehicle miles traveled by road type within the county. As this table indicates, the majority of miles

TABLE 2-6. Average Travel Speed by Road Surface in Lenawee County, Michigan*

Road Surface	Average Travel Speed (mph)
Unimproved Earth	10
Graded and Drained Earth	10
Gravel and Similar	20
Bituminous Surface Treated Gravel	30
Mixed Bituminous Surface on Gravel	35
Mixed Bituminous Surface on Concrete, Brick or Black Base	35
Concrete	40

*Source: Michigan Department of State Highways and Transportation, Planning Division.

TABLE 2-7. Average Daily Vehicle Miles Traveled by Road Type in Lenawee County, Michigan*

Road Type	Average Daily Vehicle Miles
State Trunk Line	926,729
County Primary	411,919
County Local	144,582
City and Village Major	258,660
City and Village Local	32,266
County Total	1,774,156

*Source: Michigan Department of State Highways and Transportation, Planning Division.

traveled occurs upon the state trunk lines. Fifty-two percent or 926,729 vehicle miles are traversed each day on these state, U.S. and interstate highways. The county rural road system sustains an average daily traffic flow of 556,501 vehicle miles. The county primary roads account for 411,919 vehicle miles daily and the local county roads average 144,582 vehicle miles. Within incorporated areas of Lenawee County the major streets are utilized at a rate of 258,660 vehicle miles daily and the city and village local streetways receive an average daily traffic of 32,266 vehicle miles.

2.3 Economic Characteristics

This section is designed to examine the financial responsibilities and constraints placed upon the rural transportation network. The county road commissions which are responsible for maintaining the rural road system secures its revenue base from several sources. In 1976 seven sources of revenues provided the capital to maintain and construct the rural road system.

The major source of revenues is the Michigan Transportation Fund, formerly called the Motor Vehicle Highway Fund. In 1976 this fund provided $187.5 million in revenues for the county road commissions in Michigan. County-raised funds provided $36.3 million for maintaining and constructing the county road system. Federal funds totaled $35.6 million and bonds and notes accounted for revenues in excess of $8.5 million.[4] Sale of land and buildings and miscellaneous receipts accounted for the remaining funds.

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[4] Michigan Department of State Highways and Transportation, 26th Annual Progress Report for the County Road Commissions, Incorporated Cities and Villages of Michigan, Report No. 162, Lansing, Michigan.

Monies from the Michigan Transportation Fund are distributed to each county for maintaining and constructing the county rural road system by a distribution formula based upon such factors such as road mileage, population and weight tax collections. In 1976 the county primary road system received, based upon the weight tax collected in each county, an average of 60 cents per capita. The distribution formula for mileage produced an average $510.75 per mile for the county primary road system. Each county was also allocated $237,922. The local rural road system received an average of $465.44 per mile and $5.17 per person.[5]

According to legal constraints placed upon Lenawee County by Michigan law, 20 percent of the total revenues received from the Michigan Transportation Fund must be spent on construction of the primary system. After revenues are distributed between the primary and local systems, based upon the distributional formula established by law, this means the primary road system breakdown is 60/40 on maintenance and construction, respectively. The expenditure of funds on the various projects for both maintenance and construction is determined by the Lenawee County Road Commissioners and county engineer based upon need. Funds are used to meet the most serious needs first.

The county local system funds are budgeted on an 80 percent maintenance, 20 percent construction basis. The county construction budget is then used as a matching program with the townships. As an example, on bridge construction, the county will match 50/50 with the townships on expenditure of funds and on road construction 50/50 up to a maximum of

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[5]Michigan Department of State Highways and Transportation, op. cit., p. 25.

TABLE 2-8. Construction and Maintenance Disbursements for Rural Roads in Lenawee County, Michigan*

	Construction			Maintenance		
Year	Primary	Local	Total	Primary	Local	Total
1970	354,043	438,614	792,657	442,486	579,829	1,022,315
1971	507,118	244,587	751,705	509,590	656,010	1,165,600
1972	499,365	400,757	900,122	533,343	694,275	1,227,618
1973	732,935	564,497	1,297,432	537,526	710,647	1,248,173
1974	902,928	382,483	1,285,411	938,609	722,517	1,661,126
1975	932,599	355,557	1,288,156	790,078	794,609	1,584,687
1976	876,546	377,648	1,254,194	1,252,426	631,853	1,884,279
1977	1,196,472	332,393	1,528,865	841,824	828,033	1,669,857

*Source: Michigan Department of State Highways and Transportation, Local Government Division.

$2,000. However, this matching basis is contingent upon the availability of revenues.

In 1977 combined maintenance and construction expenditures for Lenawee County's rural road network reached $3,198,722. These disbursements were fairly evenly distributed with $1.5 million being expended on construction and $1.7 million on maintenance. Table 2-8 indicates the construction and maintenance disbursements for rural roads in Lenawee County from 1970 to 1977. The mix of appropriations between maintenance and construction has varied over this 8 year period from approximately a 60/40 ratio to a 40/60 ratio in 1973 and 1971, respectively. Total expenditures have increased in each succeeding year with the exception of 1974 and 1975 when disbursements fell by $73,694. Since 1974, combined expenditures for the county primary system have exceeded expenditures on the county local network. When the expenditures are compared on a per mile basis the county primary system received more funds than the local system since 1970. When rural road expenditures are deflated to 1967 costs it is observed that combined maintenance and construction disbursements fell by 1.5 percent when comparing 1970 and 1977. Table 2-9 displays the real construction and maintenance costs for rural roads in Lenawee County. Comparing 1970 to 1977 real rural road construction increased by 3.9 percent while real maintenance expenditures on the county rural road system fell by 6.0 percent. Total real disbursements on maintenance and construction for Michigan's rural road system has been fairly constant since 1970 as compared to the U.S. real expenditures which have shown a downward trend since 1970 (see Table 1-1).

TABLE 2-9. Real Construction and Maintenance Costs for Rural Roads in Lenawee County, Michigan

Year	Construction	Maintenance	Total
		(1967 Dollars)[a]	
1970	711,925	875,270	1,587,195
1971	609,655	949,959	1,559,614
1972	692,402	932,132	1,624,534
1973	899,745	880,235	1,779,980
1974	689,968	1,047,368	1,737,336
1975	677,331	916,004	1,593,335
1976	665,355	1,001,743	1,667,098
1977	739,654	822,995	1,562,649

[a]Current 1967 dollars were deflated by U.S. Department of Transportation, Federal Highway Administration indicies for rural price trend for federal aid highway construction costs and highway maintenance and operation cost trend index.

2.4 Summary

Lenawee County's 1,642 miles of road and highway infrastructure is characterized with a mixture of road types and conditions. The road system can be classified as semideveloped, having road types ranging from concrete to unimproved earth. Road surface conditions vary substantially on the transport network. Eight percent of the road surface is rated excellent and very poor, each with the remaining 84 percent distributed among good, fair and poor conditions. The road foundation is generally in good condition. Most of the state trunk line and major streets within incorporated areas can sustain traffic flows which are of the maximum legal load. Very few of the 1,350 miles of county rural roads are capable of supporting this maximum legal load. There exists 459 miles of road and highway in Lenawee County which are determined deficient by engineering standards.

Lenawee County has 71,800 vehicles registered within its jurisdiction which utilize its road and highway infrastructure. It is estimated that close to 650 million vehicle miles are traveled on the county road system each year.

Expenditures to maintain or construct the county rural road system have been fairly constant since 1970. In constant dollars these combined disbursements have increased only slightly and have actually fallen by 6 percent for maintenance.

CHAPTER III

THE GRAIN ASSEMBLY MARKETING SYSTEM IN LENAWEE COUNTY

The intent of this chapter is to provide a description of the assembly marketing system for grain in Lenawee County. Knowledge of this marketing system is essential to the understanding of the magnitude of the research problem addressed in this thesis. The chapter has been subdivided into three components, each representing a major sector in the grain assembly marketing system. The first part of this chapter deals with the characteristics of the grain producing sector. The second section identifies and examines the grain assembly function. The last section explores the role played by grain elevators in the assembly marketing system.

In examining the grain assembly marketing function and the role that each agent plays many sources of information were used. Documentation concerning the production of grain and characteristics of the producing units were secured primarily from the Michigan Department of Agriculture and the U.S. Census of Agriculture. Information regarding the grain assembly function was provided primarily by those individuals either directly or indirectly involved in the system. The Michigan Grain and Agri-Dealers Association and managers and operators of grain elevators supplied data relevant to the role performed by country elevators in this marketing system.

3.1 Grain Production

Lenawee is the leading county in the production of grains in the State of Michigan. The major grain production is corn, wheat and soybeans. In 1977 corn accounted for almost 65 percent of the grain bushels produced in the county, soybeans recorded 19.4 percent of the grain production and wheat yielded 11.7 percent of the grain harvest. The remaining grain production was oats and barley. Table 3-1 indicates the actual production of grain in Lenawee County for 1977. The production of corn at 12,267,000 bushels, wheat at 2,220,000 bushels and soybeans at 3,669,300 bushels was the largest county production of grains in Michigan. The county production of oats and barley were ranked 5th and 33rd, respectively, in the state. The total value of grain harvested and sold by grain producers in Lenawee County was $48 million. From Table 3-1 it can be observed that corn production accounted for almost half of the grain production value at $22.7 million. Soybeans harvested were valued at $19.8 million and the wheat harvest was sold at $4.4 million. Oat production was just short of $1 million.

Almost 285,000 acres of land were devoted to the production of grain in Lenawee County. This land use represented 59 percent of the total land area in the county. Between 1974 and 1977 the farm acreage planted to grains has been on the rise. Corn acreage is up 16.7 percent to 118,000 acres, soybean acreage has been increased by 9.5 percent to 101,000 acres and the largest increase has occurred in wheat acreage which has risen 19.8 percent to 54,200 acres.

No current figures are available on the number and distribution of farms in Lenawee County. However, in 1974 there existed 2,056 farming units in the county. Of these farms, 1,467 had some corn production,

TABLE 3-1. Agricultural Production, Acres Harvested, Average Yield and Value of Grain in Lenawee County, Michigan, 1977*

Grain	Production in Bushels	Acres Harvested	Average Yield (bu/Acre)	Value of Grain ($)
Corn	12,267,000	118,000	104.0	22,693,950
Wheat	2,220,000	54,200	41.0	4,440,000
Soybeans	3,669,300	101,000	36.3	19,814,220
Oats	749,000	10,900	68.7	973,700
Barley	3,000	65	46.2	7,350
Total Grain	18,908,300	284,165		47,929,220

*Source: Michigan Department of Agriculture, Michigan Agricultural Statistics, June 1978.

1,376 produced wheat, 1,330 raised soybeans and 582 devoted acreage to oat production. The trend in grain production has been toward fewer farms, but of larger size. In 1974 the average farm size was 181 acres, up from 158 acres in 1969. The value of all land and buildings has increased also from an average of $70,260 per farm in 1969 to $125,083 per farm in 1974.

The farm type is varied in Lenawee County, but dominated by individual or family ownership. In 1974 there existed three corporate structured farms, 154 partnerships and 1,556 individual or family owned farms. Full ownership occurred on 1,249 of the farms in Lenawee County in 1974 with 625 part-ownerships and 182 tenant farmers. Fifty-three percent of the farm operators listed farming as their principal occupation.

3.2 Grain Assembly

3.2.1 Wheat

Wheat is a cool season grass which is planted in late September following the first "fly free day."[1] The wheat matures and is harvested generally after the 4th of July, but before the end of that month. The planting and harvesting of wheat is very highly mechanized in Lenawee County. According to the county extension agent, very little drying and storage of wheat takes place on the farm. Most of this grain is shipped directly to the country elevator at harvesttime.

3.2.2 Corn

Corn which is a warm season grass is generally planted from mid April to mid May and harvested at the end of September or beginning of

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[1]The first "fly free day" is the date when the Hessian flies disappear. If the grain is planted while the fly is still swarming, it deposits its eggs on the wheat which is harmful to the plant later.

October. A substantial portion of corn, according to the county extension agent, is dried and stored on the farm until spring when most of it is shipped to the country elevators. Much corn, however, is shipped at harvesttime to these elevators. Like wheat, corn planting and harvesting is highly mechanized with most corn being shelled rather than being picked, air-dried and stored on the cob.

3.2.3 Soybeans

Soybeans are a legume which are usually planted after the planting of the corn crop. This planting is generally from mid May to mid June. Soybeans are harvested mechanically also around the first of September. Like corn, some of this crop is stored on the farm until spring when it is transported to local or terminal elevators.

3.2.4 Oats

Oats are more subject to disease and insects in hot weather, so this cool season grass is planted in early spring. Most producers attempt to have the crop planted before the first of April. Oats are harvested in mid summer mechanically, often stored on the farm and transported to country elevators throughout the year.

The grain assembly function is comprised of many integral parts. Included in this system are the functions of drying, storing, transporting, scalping and blending. The grain producer in Lenawee County must undertake at least part or all of the transport function in moving grains to the intermediate local country elevators or terminal elevators located in the Toledo, Ohio area. The grain farmer can choose to undertake the drying and some storage function also, usually being rewarded by a higher price at the elevator for so doing. This research work is concerned with only the physical transportation assembly function of grain marketing, and thus, the remainder of this section will concentrate on the physical movement of grain in Lenawee County.

Grain movement in Lenawee County occurs throughout most of the year with a large concentration of the movement in spring. Movement of grain in this county, like the whole state, flows in generally a southeastern direction toward north central Ohio. The initial responsibility for transporting grain from the production units to the country elevators falls to the producers themselves. The actual cost of transport is dependent upon many factors such as distance, road condition, mode and even the timing of the transportation function. For Lenawee County, the total transportation cost of moving grain from the producing unit to the terminal elevators in the Toledo area ranges from as little as 9 cents per bushel to a high of 32 cents per bushel. Most of the grain movement in Lenawee County passes through one of the intermediate country grain elevators located within the county before reaching terminals in the Toledo area.

A variety of transport modes are used in the movement of grain. Pickups, farm wagons and farm trucks comprise the most prevalent mode of transporting grain from the farm gate to the intermediate country elevator. Because of the large grain production in Lenawee County and the fact that the average size of farm is much larger than the state average, larger capacity vehicles are used in transporting the grain production. One of the most common vehicles used in transporting grain is the single-axle farm truck of 2 to 4 ton weight. The capacity of such trucks are usually 140 bushels, although overloading is a common practice among farmers. The overload factor on these farm vehicles is approximately

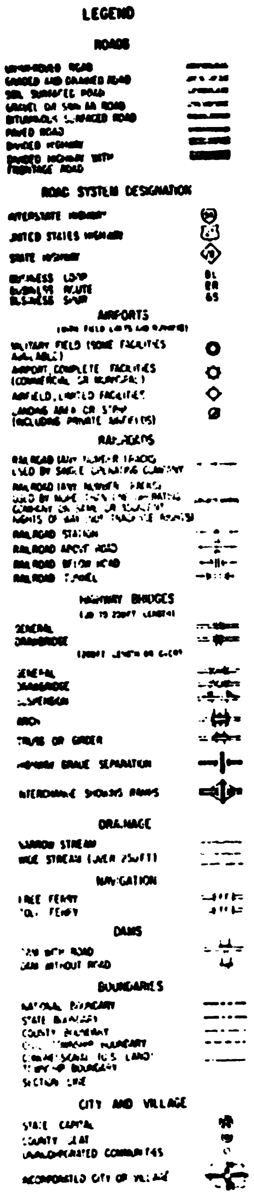
10 percent. This means most loads shipped to intermediate or terminal elevators over the rural road system are in the area of 160 bushels. The vehicle contains a single-box bed opened at the top. A canvas cover can be secured over the box to protect the contents during shipment. This single-box is sometimes mounted on its own hydraulic lift which makes unloading faster and more efficient.

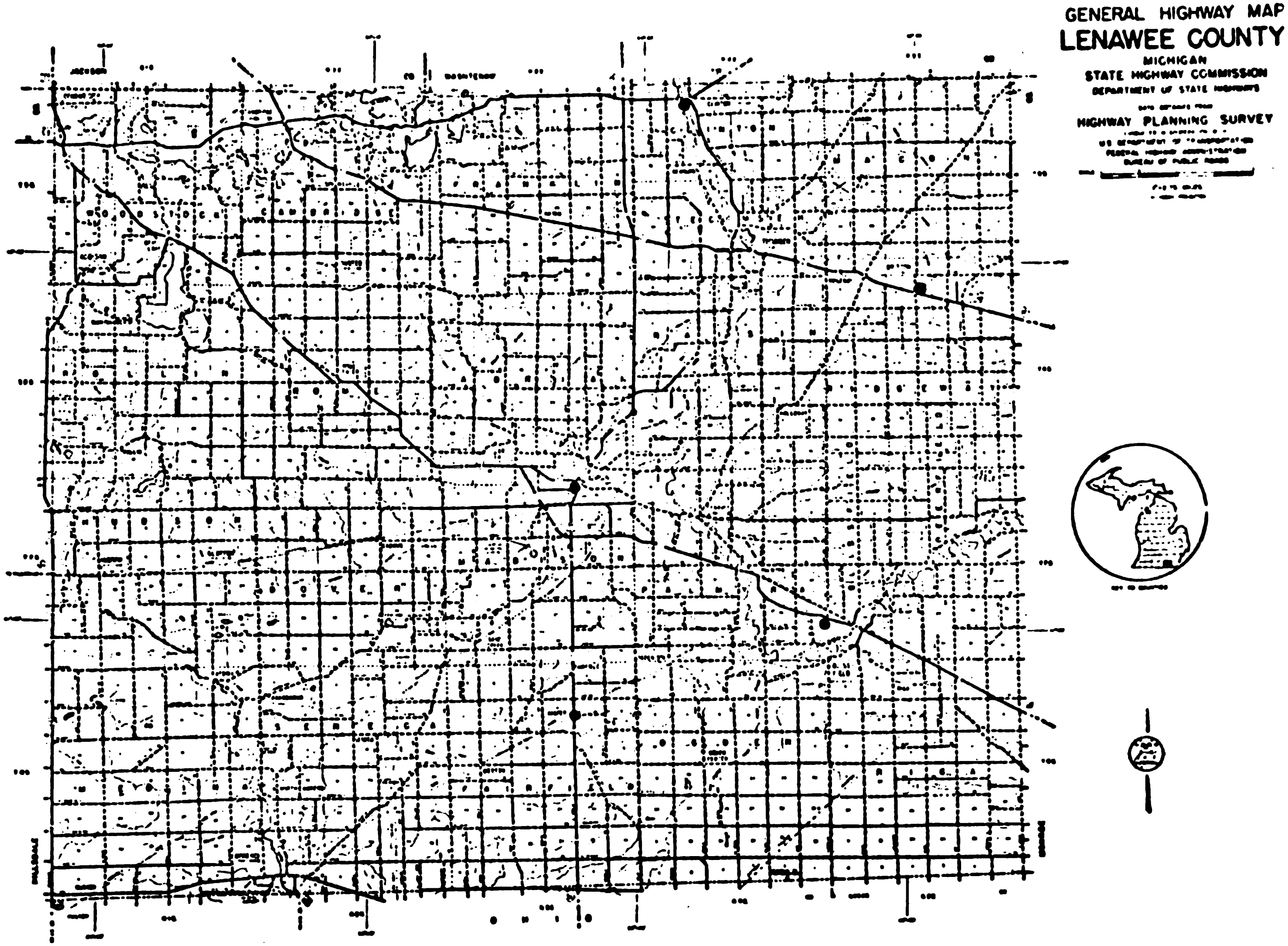
Shipments of grain from intermediate grain elevators to the terminal elevator in the Toledo area is done by truck transport only. Because of the volume of grain involved in this movement, larger vehicles are utilized. All grain shipped from the intermediate elevators are done so by 30 ton tandem-axle vehicles. These trucks are generally of the single-box bed type with open tops. To protect against weather, foreign materials and spillage, the open top is usually closed with tightly secured canvas material. The average capacity of these vehicles are 900 to 1,000 bushels of grain.

Since all the country elevators are located within easy access to major state trunk lines, operating costs of these 30 ton vehicles in Lenawee County varies primarily with the distance of movement. These line-haul operating costs range from 10 cents per bushel for a 92 mile round trip to a cost of 5 cents per bushel based upon a round trip of 46 miles.

3.3 Grain Elevators

Lenawee County is serviced by five local country grain elevators. These elevators are located in the eastern part of the county (see Figure 3-1) primarily because the major grain production is concentrated in the eastern townships. From Figure 3-1 it can be observed that all local elevators are located on major state trunk lines with easy access





Country Grain Elevators for Lenawee County

FIGURE 3-1

to the terminal elevator located in the Toledo, Ohio area. While rail transport is of little importance in grain marketing in Lenawee County, all country elevators have access to rail lines.

Besides acting as an outlet for farmers to sell or store their grain products, the local elevators provide many of the essential inputs used by these producing agents. Generally available at these elevators are many seed grains, livestock feed, fertilizer, etc.

In the grain assembly marketing system these local elevators participate in the transporting, storing, scalping, blending and drying functions. When grain is moved into the elevator, foreign matter is removed through a process of scalping which increases the grade of the grain. By blending various grades of grain, the local elevators can improve the overall grade, and hence, obtain higher prices for their grain. Because of chances of spoilage and fire, the grain must be dried before it can be stored. This drying process is usually accomplished by use of low heat dryers. Once dried, the grain is usually stored in large bins at the elevator awaiting shipment to terminal elevators or disposal by the farmer if he is simply storing and has not sold to the elevator. The transport of grain to the terminal elevator is done in 30 ton trucks. Part of this transport function is accomplished through rental agreements with contract haulers and part is undertaken by elevator owned trucks. The truck fleet involved in hauling grain from the local elevators is quite small in Lenawee County. The major hauler at Blissfield and Jasper own two trucks and contract out the grain not hauled by their company owned fleet.

Table 3-2 provides information on elevator capacity, location and operating costs of transportation. From this table it can be

TABLE 3-2. Country Elevators in Lenawee County, Michigan--Location, Capacity and Transport Costs to Toledo, Ohio, 1977*

Elevator Location	Capacity (in Bushels) Storage[a]	Effective[b]	Transport Distance to Toledo, Ohio (in Miles)	Truck Operating Transport Costs to Toledo, Ohio (Cents/Bushel)
Britton	460,000	1,150,000	35	5
Clinton	100,000	250,000	46	10
Adrian	210,000	525,000	33	8
Blissfield	1,200,000	3,000,000	23	5
Jasper	1,100,000	2,750,000	34	6

*Source: Michigan Grain and Agri-Dealers Association and telephone survey of the existing elevator operators and managers.

[a]Storage capacity is the total amount of grain which can be stored at any one point in time.

[b]Effective capacity is the total amount of grain which could be stored over a period of 1 year. Because of flows into and out of the grain elevator, effective capacity is larger than storage capacity.

observed that Lenawee County has a mixture of large and small local elevators.

Britton. The Britton Elevator is located on M-50 in Ridgeway Township. This is the eastern most elevator in Lenawee County with access to the Norfolk and Western Railroad. The elevator is within 35 miles travel distance of the terminal elevators in the Toledo area. Storage capacity at Britton is 460,000 bushels of grain with an effective storage capacity of 1,150,000 bushels.[2] The average operating cost per bushel of grain moved is approximately 5 cents.

Clinton. The Clinton Elevator is the farthest most northern local elevator in Lenawee County. Located near the intersection of M-52 and U.S. 12, Clinton is 46 miles from the terminal elevator. Storage capacity is 100,000 bushels with an effective handling capacity of 250,000 bushels. Because the Clinton Elevator is the farthest elevator from the Toledo area its transport operating costs are the highest in the county at 10 cents per bushel moved.

Adrian. The elevator located at Adrian can handle 525,000 bushels of grain per year with a storage capacity of 210,000 bushels at any one time. Located near U.S. 223 and M-52, this elevator has access to the Detroit, Toledo and Ironton Railroad which is currently under abandonment petition. Within 33 miles of the terminal elevator, the Adrian Elevator operates at an approximate cost of 8 cents per bushel in transporting grain.

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[2]Effective capacity is the total amount of grain the local elevator can handle in a year's time. Thus, the flow into and out of the local elevator provides the means by which the elevator can handle more grain than the storage capacity. Recent studies at Michigan State University suggest effective capacity is 2.5 times the storage capacity.

Blissfield. The grain elevator at Blissfield is located the closest to the terminal elevator. The Toledo Elevator is within 23 miles of Blissfield. The Blissfield Elevator has access to both U.S. 223 and the New York Central Railroad. This is the largest local elevator in Lenawee County with a storage capacity of 1.2 million bushels and an effective handling capacity of 3 million bushels. Along with the elevator at Britton, this elevator has the lowest per unit transport cost at 5 cents per bushel moved to Toledo.

Jasper. The Jasper Elevator is the most southern elevator in Lenawee County. Located on M-52 it is also served by the New York Central Railroad. The second largest elevator in the county, it has a storage capacity of 1.1 million bushels and an effective capacity of 2.75 million bushels of grain. At a distance of 34 miles from the terminal elevator, the Jasper Elevator has a cost of transport of 6 cents per bushel.

3.4 Summary

The grain assembly marketing system in Lenawee County is comprised of many functions. These functions are transporting, drying, storing, scalping and blending. The farmer usually performs some of the transport function and on occassion some drying and storage functions. The intermediate country elevators execute all of the various roles in the grain assembly marketing system. This research effort is primarily concerned only with the transportation function in this marketing system.

Grain production is the primary agricultural pursuit in Lenawee County. The leading grain producing county in Michigan, Lenawee produced 19 million bushels of grain valued at $48 million in 1977. Corn was the leading grain produced, followed by soybeans and wheat. This grain is moved over the rural road system throughout most of the year with the heaviest concentration in the spring months. Most of the grain is shipped from the farm gate to intermediate or terminal elevators in 2 to 4 ton trucks usually loaded with 160 bushels of grain. Larger vehicles of 30 ton weight and 1,000 bushel capacity are utilized in shipping grain from the local elevators to the terminal elevator at Toledo, Ohio. Both private fleets and commercial haulers are used in this shipment of grain.

Five local elevators located at Britton, Clinton, Adrian, Blissfield and Jasper serve the grain farmers' needs in Lenawee County. All five elevators are located within easy access to major state trunk lines and railroads. Storage capacity ranges from as little as 100,000 bushels to as much as 1.2 million bushels. Transport costs at these local elevators are from 5 cents per bushel to 10 cents per bushel when shipping the stored grain to the terminal elevator.

CHAPTER IV

THEORETICAL CONSIDERATIONS AND METHODOLOGICAL PROCEDURE

The purpose of this chapter is to set forth the theoretical considerations and methodological procedures employed in this research effort. Knowledge of the analytical procedures and tools is essential to understanding and formulating impact and summary implications of rural road development. This chapter is intended to demonstrate the analytical process utilized in testing the hypothesis discussed in Chapter I. This chapter has been divided into a number of sections. The first section deals with the economic model underlying the framework of analysis. The second part of this chapter develops the mathematical model built upon the economic model. The third component examines the computer model utilized in processing the empirical data collected for this thesis. The fourth section outlines the stepwise approach followed in deriving the empirical impact findings in the research. The fifth and sixth components put forth the various alternative investment or development level scenarios investigated and tested and the feasibility assumptions employed in the analysis.

4.1 The Economic Model

The economic organization of a transportation system for the marketing of grain must carefully consider two costs: (1) the actual cost incurred in transporting the grain from origin to final destination; and (2) the costs associated with handling the grain at intermediate points between the origin and final destination. The cost minimization model provides the foundation for most transportation analyses designed to solve the optimal flow pattern which minimizes the aggregate specified costs in the model. It is such a model which underlies this research investigation.

The nature of this research problem is the determination of the optimal commodity flow pattern and aggregate costs associated with various rural road investment scenarios. In researching this problem the emphasis was placed upon minimizing the aggregate transportation costs of hauling grain from the production regions to the intermediate local grain elevators and/or terminal elevator and costs associated with handling the grain between the local grain elevators and the terminal grain elevator. The importance of transport cost minimization to grain farmers and grain elevator operators alike is that ceteris paribus cost reductions implies higher profits for the economic entity, and assuming these economic actors to be rational, they will attempt to maximize profits according to established economic theory. Improved efficiency has implications for consumers and society in general.

Two simple diagrams illustrate the degenerating nature of and optimal solution to the transportation problem. Figure 4-1 depicts the initial situation for a single production region and two country elevators. Line ab is the amount of grain which can be moved to either or both grain elevators E_1 and/or E_2. $C_1 C_1$ is the capacity constraint for grain elevator E_1 and $C_2 C_2$ is the capacity constraint on grain elevator E_2. The feasibility region is defined by the triangle a0b. The optimal solution is dependent upon the slope of the transport cost line PP, but generally will be a corner solution at either a or b, the point of tangency with the cost line and the boundary of the feasibility region. As the grain elevators fill up with the grain from regions with smaller transport costs, the capacity constraints in subsequent shipment diagrams are compressed to smaller restrictions. This is illustrated in Figure 4-2. The new and smaller capacity constraints become C_1^1 C_1^1 for grain elevator E_1 and C_2^1 C_2^1 for grain elevator E_2. The new feasibility region now becomes f d e g 0 and the optimal solution, defined by the tangency of the transport cost line and the boundary of the feasibility area will generally be located at d or e. Summing these diagrams provides the optimal solution to the transportation problem.

4.2 The Mathematical Model

The mathematical formulation of the model used in this research analysis is based upon the transportation model employed in linear programming analysis. Snodgrass and French[1] presented the mathematical solution to the transportation problem. In this research the transportation model deals with the problem of distributing a homogenous commodity (grain) from several spatially separated sources of production to several spatially separated sources of consumption (country elevators). Thus, given a homogenous commodity and:

C_i = the production capacity in units (bushels) of the commodity at the production source i;

D_j = the effective capacity of the country grain elevator located at j;

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[1]Snodgrass, Milton M. and Charles E. French, "Simplified Presentation of 'Transportation-Problem Procedure' in Linear Programming," Journal of Farm Economics, Vol. 39, No. 1, February 1957, pp. 40-51.

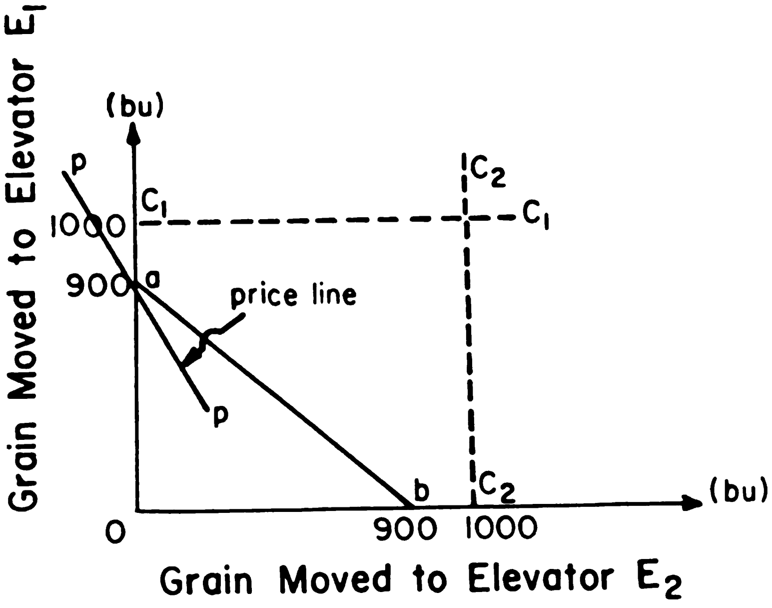


FIGURE 4-1

Optimal Solution to the Transportation
Linear Programming Problem--Part 1

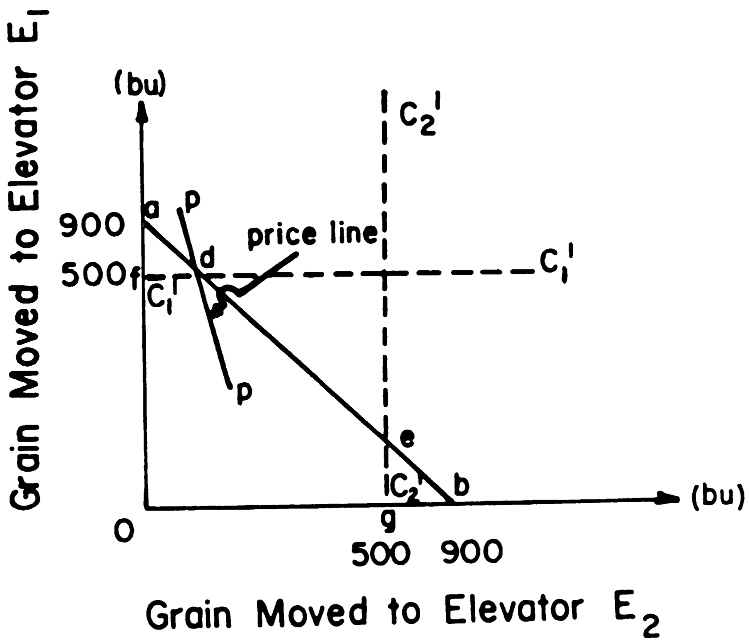


FIGURE 4-2

Optimal Solution to the Transportation
Linear Programming Problem--Part 2

t_{ij} = the sum of the transport assembly and handling costs of moving a single unit of the commodity from i to j;

x_{ij} = the amount of the commodity shipped from i to j.

The problem then is to:

$$\text{Minimize:} \quad \sum_{i=1}^{m} \sum_{j=1}^{n} t_{ij}\, x_{ij} \tag{1}$$

$$\text{Subject to:} \quad \sum_{i=1}^{m} x_{ij} \leq D_j \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} = C_i \tag{3}$$

$$x_{ij} \geq 0 \tag{4}$$

The solution of the transportation problem equation (1) provides the optimal commodity flow of grain at the minimum aggregate transportation assembly and handling cost. Constraint (2) insures that no more grain will flow to an elevator once the elevator's grain capacity or handling ability is reached. Constraint (3) moves all the grain production for each producing region through the marketing system. Negative grain movement is prohibited by constraint (4).

4.3 The Computer Model

The computer model utilized in this research analysis was the transportation linear programming model. The software employed in this analysis is known as the "Agricultural Economics Linear Program Package: Version 2" developed and made operational at Michigan State University in April of 1975. This particular linear programming package was executed on the CDC-6500 computer and is designed to handle modest-sized linear programming transportation problems. The computer model is intended to solve for the optimal commodity flow which will minimize the aggregate transportation costs in the system.

In this research study of analyzing the optimal commodity flow patterns and aggregate transportation costs resulting from various rural road development scenarios the resulting transportation matrix was formulated into two distinct parts. These parts or activities as they are known in linear programming are:

(1) The supply regions which are the points of origin for the commodity flow. These are defined as the grain producing areas of which there are 26 in this study.

(2) The elevator consumption regions are points of intermediate and final destinations for the grain flows. These regions locate the six country elevators within this research project.

The matrix size for the transportation problems investigated were comprised of 32 rows and 156 columns. The first 26 rows represented the supply regions or production points. These activities reflect the grain production in these 26 regions. These rows are treated as equalities. The next six activities represented one of the six elevators to which the grain could be shipped. Five of these activities were for one of the five local grain elevators serving as intermediate stoppage of the grain before reaching its final destination. The capacity constraint sign placed upon these five activities was "less than or equal to." The final activity represented the terminal elevator to which all the grain flowed. Since the grain production in this study region flowed to the single terminal elevator, its capacity constraint was the "greater than or equal to" sign.

Table 4-1 provides an illustration of how the transportation problem matrix was constructed and appeared in the analysis. The matrix was constructed by this author as a modified form of a transshipment model. This was done so because of the relative ease of manually manipulating the cost data so it would fit into a linear transportation programming form and the desire to reduce the dimensions of the matrix for efficiency in calculations.

Table 4-1 contains three supply regions (S_1, S_2 and S_3), two intermediate country elevators (C_1 and C_2) and one terminal elevator (C_3). These six activities are the six rows under the heading locations. The column headings S_1 C_1 through S_3 C_3 represent the activity of shipping grain to one or more of the three elevators, either C_1, C_2 or C_3, from one of the supply regions S_1, S_2 or S_3. As an example, S_2 C_1 is the activity of shipping grain from the second production region (i.e., S_2) to the first local grain elevator (i.e., C_1).

A close examination of the matrix in Table 4-1 reveals the two constraints (2) and (3) discussed in the mathematical model. The rows labeled C_1, C_2 and C_3 relate to the capacity constraints of inequality (2). Row C_1 contains the value 1 in columns 1, 4 and 7 and the value 0 in the remaining columns. This row indicates that the sum total of all grain shipped to elevator C_1 from all production regions S_1, S_2 and S_3 must be less than or equal to 1,150,000 bushels. Rows C_2 and C_3 are interpreted in the same manner. Constraint (3) is meant by rows S_1, S_2 and S_3. Row S_1 which contains unit values in the first three columns and 0 elsewhere is interpreted to mean that the summation of all grain shipped from supply region S_1 to all elevators C_1, C_2 and C_3 must be exactly 80,200 bushels. Rows S_2 and S_3 are interpreted in the same manner.

TABLE 4-1. Matrix Format of the Linear Programming Transportation Model

Locations		S_1 C_1	S_1 C_2	S_1 C_3	S_2 C_1	S_2 C_2	S_2 C_3	S_3 C_1	S_3 C_2	S_3 C_3	Constraints
Supply	S_1	1	1	1							= 80,200
Region	S_2				1	1	1				= 80,200
	S_3							1	1	1	= 80,200
Elevator	C_1	1			1			1			$\leq$ 1,150,000
Consumption	C_2		1			1			1		$\leq$ 3,000,000
Region	C_3			1			1			1	$\geq$ 0
Unit Cost of Transport		-9	-13	-14	-9	-14	-14	-8	-13	-14	

Located at the bottom of Table 4-1 is a row of negative numbers. These figures represent the respective costs per bushel to move and handle the grain being shipped from each supply region to the terminal elevator via any local elevator. In column S_1 C_1 is found a figure of -9. This is interpreted to mean that for every bushel transported to the terminal elevator (C_3) via local intermediate elevator (C_1), the aggregate transport and handling cost is 9 cents. Column S_1 C_3 represents the cost of transport in directly shipping to terminal elevator C_3 from production region S_1. The numerical value of -14 signifies a cost of 14 cents per bushel moved. These figures have a negative sign before them indicating a cost involved in the movement of grain to satisfy the constraints in this problem. The computer program is designed to maximize the value of the objective function. By placing a negative sign in front of each value in the objective function forces the computer to find the smallest negative value, and hence, minimizes these transport costs.

The computer model generated a significant amount of information. The output obtained through this computer model was the following:

(1) The quantity of grain shipped from each production region.

(2) The destination of the grain shipped from each production region.

(3) The quantity of grain received at each country elevator.

(4) The origin of the grain shipped to each country elevator.

(5) The aggregate transport and handling cost involved in the shipment of all grain in the marketing system.

(6) The marginal cost of grain shipment at each supply region.

(7) The marginal value of increasing grain elevator capacity by 1 bushel.

4.4 The Analytical Procedure

In order to investigate the economic impact upon grain producers and country grain elevators of rural road development, it was necessary to generate data of sufficient quality, quantity and form. These data were used to analyze the economic benefits and costs of various investment scenarios. The following nine step procedure was used to develop the data:

4.4.1 Selection of a Research Area

The selection of the geographical area to study was the first critical step in this investigation. Careful consideration had to be given in the selection of a research area to ensure against potential biases in the analytical results. The selection of a region with a highly developed road and highway infrastructure would have tended to understate the economic impact of development with regard to the typical road infrastructure existing in Michigan and the U.S. Likewise, choosing a road and highway system which was extremely underdeveloped would have overstated the economic consequences. Since the central focus of this thesis was rural road development impacts, the selection of a research area with a mixture of road types and conditions was of prime importance.

Another consideration in selecting a "good" geographical area of study was road and highway usage. In order to better measure the economic impacts of rural road development, the rural road network must be moderately to heavily used. A region of low agricultural activity generates lower traffic volumes on rural local roads than do areas of higher agricultural activity. Therefore, another criteria of importance in selecting an area of research was the degree of agricultural production taking place which required transportation services.

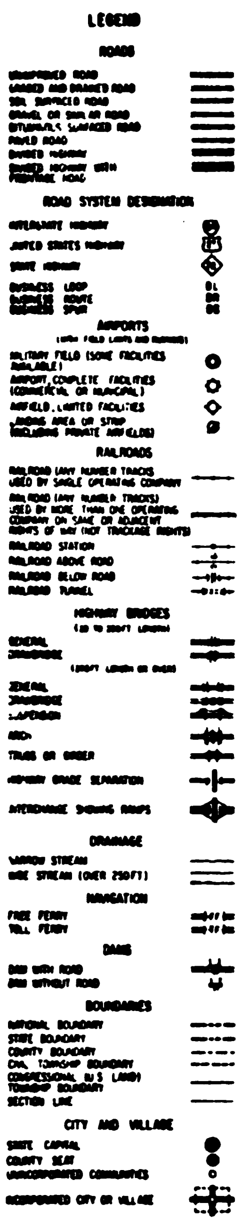
Several potential regions of the State of Michigan were identified based upon the degree of road and highway development and agricultural production. Secondary criteria such as geographical configuration and highway planning considerations, as were discussed in Chapter I, were the determining factors in the choice of Lenawee County, Michigan as the research area.

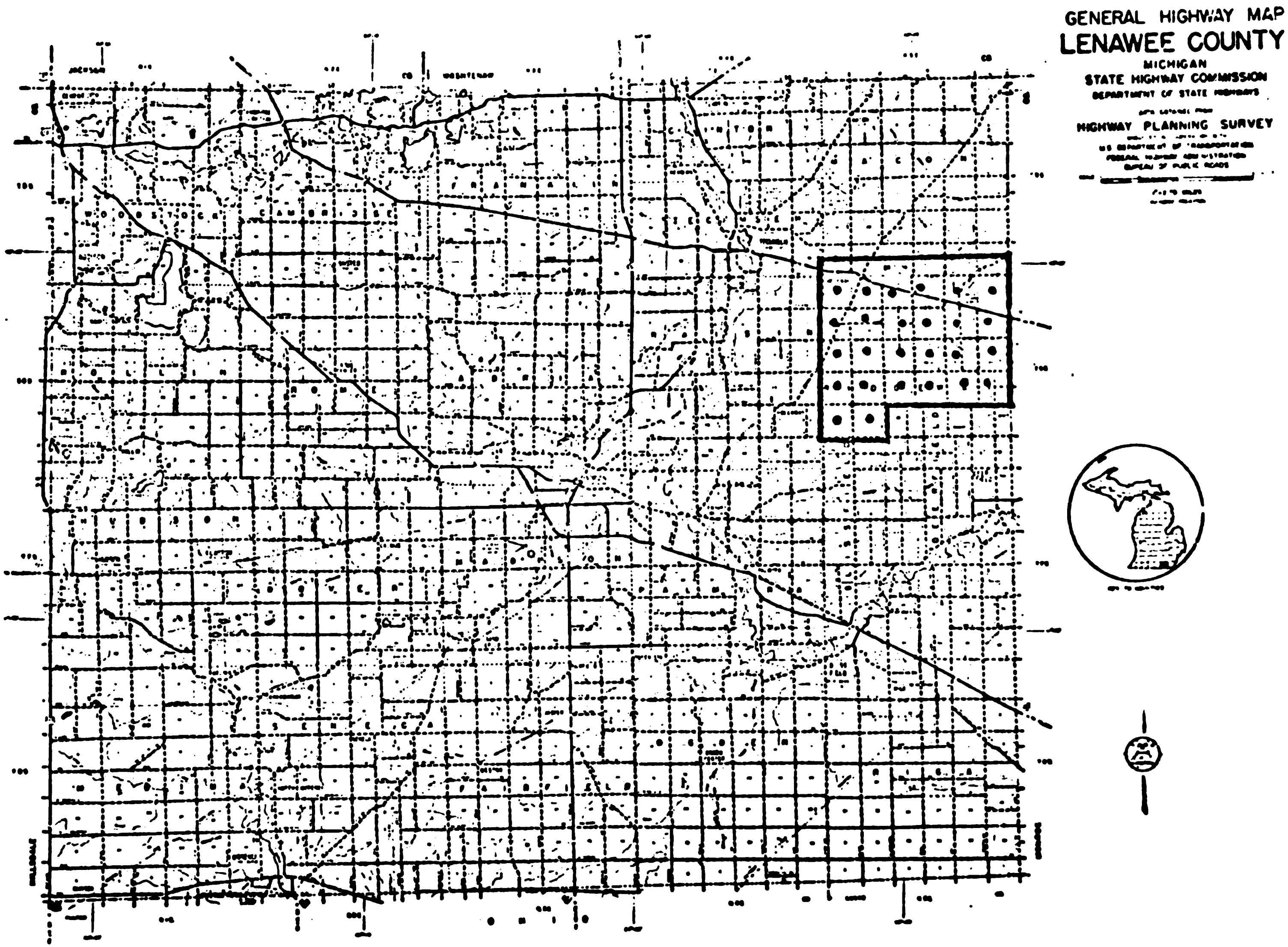
4.4.2 Location and Volume of Grain Production

The second step in this analytical procedure involved the designation of grain production regions and an estimation of the grain produced and transported from each production point. Chapter V presents a more detailed explanation of the estimation procedure and empirical results for grain production. Therefore, suffice it to say that the 1977 grain production was estimated for the entire production region and appropriately distributed among the various production points.

The political boundaries of Ridgeway Township delineated the region in which production movement was studied. Ridgeway is one of the 22 townships within the study area and is located in the northeast section of Lenawee County. This smaller region was chosen to reasonably ensure that the optimal movement of grain from the various production centroids to the country elevators identified in this study would indeed be expected to flow only to those local elevators identified and not to points outside the study area.

Twenty-six production points were defined in this study. Figure 4-3 displays the physical location of each production centroid and the political boundary of the production region, Ridgeway Township. Each





Grain Production Centroids for Ridgeway Township

FIGURE 4-3

production point encompasses approximately 1 square mile of area and was defined by the existing road infrastructure. The geographical center of each production area identified the production centroid. The use of township plat maps to identify the location of all farming units enabled the estimation of the initial commodity flow direction from each centroid. Thus, the rural road along which most of the farmlands were adjacent was defined as the route to which the grain production outflow was initiated.

4.4.3 Location and Capacity of Grain Elevators

Grain leaving the production regions is initially sent to country grain elevators. The third step in this analysis then was to locate these consumption points known as country grain elevators and estimate the amount of grain which they could handle. With the cooperation of the Michigan Grain and Agri-Dealers Association and the local grain elevators this task was accomplished.

Six grain consumption points were identified in this study, five local grain elevators in the county and a terminal elevator outside the State of Michigan (see Figure 3-1). It is estimated that because of the operating characteristics of local grain elevators in which grain is continually flowing through, an average grain elevator can handle and process 2.5 times as much grain as storage capacity per year. Thus, the actual capacity of each elevator was determined and multiplied by a factor of 2.5 which gave the effective capacity of each elevator. To determine the location of the country elevators and their respective storage capacities, each owner or manager was interviewed by a telephone survey.

4.4.4 Computerization of the Research County

Because of the complex nature of the county road and highway system and the tens of thousands of pieces of information on this network, the county road and highway infrastructure was computerized as the next procedural step. This enabled faster, easier and more efficient manipulation of the data needed in this research effort.

The Michigan Department of State Highways and Transportation provided the computer facilities and data base for this undertaking. Previously, a "Needs Study" was conducted by this agency and the information gathered was placed on computer tape. Information obtained through this engineering survey study included road surface, road type, condition, base factor, shoulder conditions, etc., for each segment of infrastructure in the county. Appendix A, Michigan Highway Needs, lists the 42 items which were computerized for each road segment. Road segmentation was delineated by both physical and engineering characteristics. Physical segmenting included defining road sections by natural or man-made boundaries such as road intersections, bridges, rivers, lakes, etc. Engineering segmentation was used to define road sections based upon technical boundaries such as changes in road surface (e.g., gravel, earth, concrete, etc.), traffic lanes, etc. Road segments ranged from as small as 0.05 miles to many miles in length.

Initially, each road segment was identified off the computer printout and placed on a master map with the proper identifying codes listed for each segment. This master map was next placed on a X, Y grid with the X-axis defining the southern boundary of the county and the Y-axis defining the western boundary. Each segment on the road and highway system was then assigned two pairs of X, Y coordinates and the appropriate identifying code which corresponded to the "Needs File" tape. Once this was accomplished, the complete network became operational and changes in the road and highway infrastructure could be brought about in the computer (e.g., changing road types) and the results calculated (e.g., changes in driving times). Appendix B provides the completely integrated computer map of Lenawee County. Appendix C indicates how changing the road surface changes the route taken when the objective function is to minimize driving time.

Next, the location of each production centroid was placed in the system and connected to the appropriate road segment. In the same manner each grain elevator was located and connected into the road and highway network. The terminal elevator was linked into the system via the major state trunk lines running from the county to Toledo, Ohio. This procedure now allowed the computer to calculate the driving times and distance between each production point and each local and terminal grain elevator.

4.4.5 Average Operating Speeds

The fifth procedural step in this analysis was the derivation of the average operating speeds between each production center and each grain elevator. To accomplish this a computer algorithm developed by the Michigan Department of State Highways and Transportation was employed in conjunction with the computerized road and highway network. Based upon safety engineering standards, each segment link on the computerized road and highway network was assigned an average operating speed as determined by the link road type and condition. Appendix D indicates the average speed of travel by road surface type as determined by safety engineering standards. The computer algorithm then traced out the path from each production region to each grain elevator based upon minimizing the travel time. Such physical path tracings can be seen in Appendix C. The computer then calculated and printed out the time in minutes required to go from each production center to each elevator and the distance in miles of the route taken.

Utilizing the distance/time relationship given by the following equation:

$$\frac{\text{(distance traveled in miles) x (60 minutes)}}{\text{(total travel time in minutes)}} = \text{mph}$$

the average operating speed was determined for each path. This process was repeated for each investment scenario investigated in this research.

4.4.6 Grain Transport Costs

Having determined the various transportation routes and average operating speeds, the next procedural step involved developing a methodology for estimating transportation costs. The estimation of these costs accounted for factors such as vehicle depreciation, driver's wages, oil, fuel, insurance, taxes, etc. This operating cost was developed into a schedule of costs relating the vehicle mile expenditure at various operating speeds. This schedule of transportation costs was derived by modifying a 1973 transportation cost study done by the Interstate Commerce Commission. Chapter V presents a more detailed discussion of this study and how the transport costs utilized in this research were developed and estimated.

Total line-haul costs of moving grain from a production point to a grain elevator was then easily derived by multiplying the appropriate vehicle mile cost as determined by the average operating speed over that route by the total round-trip distance. This figure was then divided by the total bushels moved from that given production region to determine the cost per bushel of grain transported to that given grain elevators. These transport costs were added to handling costs at each elevator and become the parameter values used in the transportation linear program as previously discussed in this chapter.

4.4.7 Grain Handling Costs

This is the seventh procedural step involved in establishing the costs associated with grain handling. This is a cost which must occur at each intermediate elevator before the grain reaches its final destination at the terminal elevator. The physical movement of grain through the system via an intermediate stopping point involves an added cost associated with handling the grain. This handling cost is essentially the expense for unloading the incoming shipments from smaller vehicles, consolidating the shipments and finally loading the grain onto larger vehicles for movement to the terminal elevator.

The estimation of handling costs were determined by telephone surveys with the intermediate country elevator operators. The reported handling costs associated with all grains average 3 cents per bushel.

4.4.8 Rural Road Maintenance and Construction Costs

To serve as a point of reference for evaluating the benefits derived through rural road development, the costs of such development must be known. The eighth procedural step in the analysis was designed to approximate such costs. Appendix E and F provide such data. Appendix E displays the annual maintenance cost per mile by surface type and number of lanes and Appendix F indicates the cost of construction per mile by surface type being upgraded to a bituminous surface. These cost figures were secured from the Michigan Department of State Highways and Transportation Planning Division.

In evaluating the cost of construction which had an expected life of 12 years it was necessary to determine the annual cost for comparison with the present benefits derived by agricultural grain producers and elevator operators. The critical variable in estimating the annual resource needs is the discount rate. This discount rate used in this study was 10 percent. This figure was used because it represented the approximate rate being paid on municipal and state bonds. Utilizing the accounting formula for determining the annual principal and interest costs needed to meet the financial liability, the total annual construction cost of improving those roads used by grain producers and elevator operators was calculated.

4.4.9 Optimal Commodity Flow and Minimum Aggregate Assembly Cost

The final procedural step in this research was the determination of the optimal commodity flow for grain and the minimum aggregate assembly cost associated with this optimal commodity flow. To achieve this, a transportation linear programming package was used. To make this transportation linear programming model operational, the following parameter values discussed in this section were used:

(1) The transportation costs were defined as the sum of the transport costs and handling cost for shipment to the terminal elevator.[2] These costs became the values in the objective function to be minimized.

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[2]These costs were actually transshipment costs since they included the total cost of transport from producer to local country elevator and then from local country elevator to terminal elevator.

(2) Grain production was estimated and evenly distributed among the 26 production centroids. The grain production in bushels for each production region then became an operational constraint in the model. Such a model forced all grain produced to be moved through the system to the terminal elevator.

(3) The local elevator capacity was determined and the effective capacity calculated. These calculations then served as the limiting constraints on how much grain could be shipped to each local elevator.

The solution of the transportation problem by linear programming techniques provided: (1) the optimal commodity flow path for grain production; (2) the minimum aggregate transport and handling cost associated with this optimal flow; and (3) the marginal values on each of the constraints.

This transportation linear programming model was operated six different times for the six investment scenarios investigated. These various investment scenarios are discussed in the following section of this chapter. The parameters discussed in articles (2) and (3) remained unchanged in each computer run. Only parameter (1) relating to transportation costs changed as the rural road network was either improved or allowed to deteriorate.

4.5 Alternative Solution Models

Six alternative investment scenarios were examined in this research analysis. This was undertaken to estimate the differing potential impacts to agriculture of changing local investment policies. In Michigan the County Road Commission, as established by law, has the responsibility of constructing and maintaining the county road system. Their decisions on not only how much to appropriate to construction and maintenance, but where it is distributed impacts upon the agricultural sector of the local economy. The following investment scenarios were considered in this research analysis.

4.5.1 Investment Scenario I

In this particular investment plan the goal is to maintain the rural road system as it presently exists within the research area. No improvements or deterioration of the infrastructure occurs under Investment Scenario I.

4.5.2 Investment Scenario II

This investment plan is designed to make improvements to the existing rural road structure in Lenawee County. Funds are assumed to be allocated in such a manner as to allow all earthen, gravel and tar sprayed roads used in transporting grain to be reconstructed. These rural roads are redesigned to become asphalt paved thoroughfares.

4.5.3 Investment Scenario III

Deterioration in the existing rural road system is allowed to occur under Investment Scenario III. Under this investment strategy the county primary system is maintained to existing standards, but no maintenance or construction occurs on the county local roads over a 5 year period. This investment scenario and the remaining three are realistic to assume. In past years revenues devoted to rural road maintenance and construction have failed to keep pace with such costs as inflation continues to soar. The revenues collected for maintenance and construction are primarily from a set fuel tax and weight tax on vehicles. These taxes have not been increased recently. Better fuel economy and lighter vehicles have served to compound the problem of rural road financing. With falling real revenues, the local County Road Commissions must face some difficult resource allocation questions. Indications are that any severe cuts in funding will be at the expense of the local county roads as attempts will be made to maintain the county primary system as it now exists.

4.5.4 Investment Scenario IV

Like Investment Scenario III, this investment plan is a deterioration model. This investment scenario is designed to preserve the county primary system at the expense of allowing the county local network to deteriorate over the next 10 years.

4.5.5 Investment Scenario V

Investment Scenario V is designed to analyze the economic consequences to agricultural producers of a 15 year deterioration of the local county roads. The primary county road system, as before, is maintained to the existing standard.

4.5.6 Investment Scenario VI

The last investment strategy is the most dramatic deterioration model. In this investment plan the County Road Commission allocates funds sufficient enough to maintain the primary rural roads, but no maintenance or construction occurs over a 20 year period on the county local rural road system.

4.6 Feasibility Assumptions

In any dynamic economic system it becomes imperative that many simplifying assumptions must be made in order to make the analysis feasible. Analyzing the economic consequences of rural road development is no exception. The number of exogenous variables which impact upon the endogenous variables in this analysis are numerous. It becomes impossible from both a practical and financial perspective as well as a time constraint to incorporate into a model all the possible variables. Thus, certain feasibility assumptions must be made to make this research possible. The major simplifying assumptions include the following:

(1) Grain production is assumed to occur at a single geographical point and not a geographical region. This assumption may have the tendency to either overstate or understate the distance involved in the actual movement of grain. However, because of the large number of production points this problem may in the aggregate be offsetting.

(2) Grain production is assumed to be uniformly distributed among the various production points. This assumption was necessitated by a real lack of production data at such a disaggregated level. It is believed that this assumption is not too unrealistic since land fertility is constant in the production area and no single farm has a large competitive edge over other units.

(3) Grain on-farm storage is assumed to be of no greater duration than 1 year. This assumption assures that all grain produced in 1 year will be moved through the marketing system. The actual on-farm storage capacity in Lenawee

County plus prevailing farm practices indicate this is a realistic assumption.

(4) Grain movement is assumed to occur by means of a 2 to 4 ton farm truck with a single bed attached. Given the size and operating procedures of farming units in Lenawee County, this model movement assumption seems quite appropriate.

(5) The economic units in the model are assumed to be characterized by rational profit maximizing behavior. Working in an environment approaching pure competition where the grain producer cannot affect the price he receives for his grain he will attempt to minimize all costs. Therefore, it is assumed that the economic actors in this model will attempt to minimize the cost of handling and transportation.

(6) It is assumed that all transportation cost functions are identical for each production region. Only distance and average operating speed are assumed to affect the per bushel cost of transportation. This assumption is a fair treatment of transportation costs since it is assumed the same type vehicle is used uniformly throughout the production region and geographically this region is relatively flat.

(7) In the selection of routes to be taken from one point to another it is assumed that the criteria are based upon minimizing time. This assumption follows logically from the cost minimization assumption. The major variable in calculating transport costs is the vehicle operator's wages or opportunity cost. As time involved in travel is diminished, cost also falls.

(8) In moving the grain produced it is assumed that all of the commodity is shipped to the terminal elevators located in the Toledo area either directly from the production region or by way of an intermediate country elevator. This is perhaps not an assumption, but a statement of reality. The actual flow pattern in Lenawee County does closely follow this assumption statement although it is suspected some leakage occurs in the system.

(9) Grain elevators are assumed to operate in a perfectly competitive market where price differentials paid for commodities reflect only transportation costs. Thus, producers face relatively competitive prices which do not affect the movement of grain or their decisions where to sell. It is further assumed that no price changes occur in any region during the analysis.

(10) During the analysis in this research it is assumed no exogenous variables interact with the grain elevator operators to make them want to increase their storage capacity.

(11) It is assumed that all grain shipped from the intermediate local grain elevators depart by truck only. The vehicles used in transporting such grain is assumed to be 30 ton trucks. Again, this assumption is a mirror of the environment in which the elevators operate. All intermediate grain elevators utilize 30 ton vehicles and no grain has been shipped by rail for over 5 years.

(12) In moving grain from each production centroid it is assumed that the existing bridge structure does not constrain the movement of the 2 to 4 ton grain hauling vehicles.

4.7 Summary

This chapter has been intended to explore the theoretical considerations and methodological procedures applied to this research work. The nature of this research problem has been to determine the optimal commodity flow pattern and aggregate transportation costs under six investment scenarios. The scenarios included improving the rural road and highway network, maintaining the existing system and deteriorating the county local roads.

In order to accomplish this analysis, an economic model concerned with minimizing the aggregate transport and handling costs in the system was used. A transportation linear programming equation constituted the mathematical model employed. This model was designed to minimize the transportation costs subject to a set of constraints on grain production, commodity movement and grain elevator effective capacity.

A nine step analytical procedure was employed in the analysis. The various steps included: (1) the selection of a study region; (2) the location and estimation of the volume of grain produced; (3) the location and determination of the capacity of grain elevators; (4) the computerization of the research county; (5) the derivation of average operating speeds between production regions, intermediate country elevators and the terminal elevator; (6) estimation of transport costs; (7) estimation of grain handling costs; (8) establishment of rural road maintenance and construction costs; and (9) determination of the optimal commodity flow pattern and minimum aggregate transportation cost.

To make the analysis feasible from a practical and financial perspective as well as a time constraint it was necessary to establish feasibility assumptions. These assumptions were: (1) grain production occurred at a single point; (2) production was uniformly distributed; (3) storage of grain was for 1 year or less; (4) grain was moved from farms by 2 to 4 ton farm trucks; (5) economic actors are characterized as rational profit maximizers; (6) transportation cost functions were identical for each production region; (7) route selection was based upon minimizing time; (8) all grain eventually flows to the terminal elevator; (9) prices remain constant and are competitive; (10) grain elevator storage capacity remained constant; (11) all grain shipped from local intermediate elevators was by 30 ton trucks; and (12) existing rural bridges did not constrain the flow of grain from producers to grain elevators.

CHAPTER V

ESTIMATION AND PROJECTIONS OF ASSEMBLY COSTS AND TRANSPORTATION DEMAND FOR GRAIN IN LENAWEE COUNTY

This chapter is devoted to a more detailed discussion of the methodology employed in estimating the demand for grain transportation and transport costs than was presented in Chapter IV. The estimations obtained from these methodological procedures are derived in this chapter and serve as part of the data base for the computer analysis. The chapter is divided into three sections, each covering a specific estimation. Section 5.1 estimates the derived demand for transportation services through developing grain production for Lenawee County and appropriating the production to production centroids. Section 5.2 is intended to develop the operating costs associated with the physical transportation of grain between production centroids and grain elevators. Section 5.3 is devoted to estimating the costs related to maintaining and constructing the rural road infrastructure. The primary source of data to enable these estimations and projections to be made were secured from governmental agencies. The three principal sources were the Michigan Department of State Highways and Transportation, the Interstate Commerce Commission and the Michigan Department of Agriculture.

5.1 Estimation and Appropriation of Regional Grain Production

As a result of the aggregation problem inherent in governmental sources of data, it became necessary to attempt to disaggregate the official census output. In order to obtain an estimation of the demand for transportation services it was essential to not only know how much production occurred, but also where. Information gathered by the Michigan Department of Agriculture on statewide grain production was available only at the county level. The problem then became one of distributing the Lenawee County grain production to the appropriate production centers within the study area. To estimate the 1977 production of grain for the production region and then apportion it among the production centroids the following steps were accomplished.

5.1.1 Selection of the Production Region

The first step involved the selection of a representative region within the study area out of which the flow of grain could be investigated. Considerations in the selection of such a production region included: (1) grain producing potential; (2) geographical location with respect to the country grain elevators; and (3) degree of rural road development. The first criteria, grain producing potential, was designed to insure that the region chosen produced a sufficient enough supply of grain for transport in order to better able measure the economic consequences of rural road development. Because of the sandy soil characteristics of the western half of Lenawee County, this criteria dictated the production region be located in the eastern portion of the county. The second consideration in choosing a production region is an attempt to insure that the actual production would in all probability be transported to the grain elevators identified in this research. Therefore, the production region must not be located close to grain elevators in neighboring counties to Lenawee County. Furthermore, because grain in Michigan generally flows in a southeastern direction, the production region had to be geographically located as much as possible southeast of grain elevators not identified in the study. Finally, the production region had to have a representative mix of rural road types and conditions. This criteria was designed to make sure that the empirical results of the analysis were not biased. This was discussed in Chapter IV under the section "The Analytical Procedure." These three criteria were met best by Ridgeway Township. Ridgeway Township is a fertile grain producing area encompassing approximately 26 square miles of area and is located in the northeastern portion of Lenawee County. Figure 4-3 defines the geographical location of the production region in this research.

5.1.2 Assignment of Production Centroids

Once the production region was chosen, the next task involved the locating of production points or centroids. This was necessitated by the characteristics of the transportation linear programming model employed in the analysis. In the linear programming model grain can flow only between specifically designated points and not regions or areas. Therefore, such points must be established to represent geographical areas of grain production. In order to closely represent areas of grain production each centroid must specify a defined or bounded region and must typify a relatively small number of grain producers. The most logical boundaries to utilize in this research was the matrix formed by the road network itself. The road system in Ridgeway Township was constructed in such a pattern that the areas defined were approximately 1 square mile. Thus, the township could be concisely defined into 26 production areas represented by 1 of 26 production points. This number of centroids, so defined, was of sufficient number to portray the individual producing units.

Lacking sufficient data on grain production on such a micro level, the production centroid was assigned the geographical center of each area. The determination of the road upon which the grain initially flowed to form such a central point was based upon the location of the farming units. Utilizing a plat map of Ridgeway Township, the location and size of each farming entity was determined. The initial entrance upon the rural road system was at the point where the vast majority of the grain production occurred.

5.1.3 Estimation of Regional Grain Production

To estimate the 1977 grain production for Ridgeway Township it became necessary to devise a distributional methodology. Grain production data was available only on a county basis from the Michigan Department of Agriculture. To distribute the 1977 Lenawee County grain production it became necessary to evaluate the historical township production data collected every 5 years by the Census of Agriculture. Unfortunately, this practice of presenting township data was discontinued and more recent figures do not display this fine a level of data collection. However, based upon the limited amount of information available, a distribution scheme was developed reflecting primarily the 1959 census data. This distributional methodology procedure and results were confirmed by the local county extension agent as being relatively accurate and portraying actual conditions in Ridgeway Township. Table 5-1 displays the township production by grain produced for 1977. As can be observed from this table, Ridgeway Township produced 2.1 million bushels of grain, representing 11.1 percent of the total county production.

TABLE 5-1. Grain Production by Type for Lenawee County and Ridgeway Township, 1977*

Grain	Production in Bushels: Lenawee County	Production in Bushels: Ridgeway Township	Distributional Factor
Corn	12,260,000	1,263,500	0.103
Wheat	2,220,000	166,500	0.075
Oats	749,000	72,700	0.097
Barley	3,000	100	0.040
Soybeans	3,669,300	594,400	0.162
Total	18,908,300	2,097,200	

*Source: 1959 Census of Agriculture and Michigan Agricultural Statistics, June 1978.

5.1.4 Appropriation of Regional Grain Production

Since no data, historical or otherwise, are available at a level smaller than a township, it became necessary to establish a method to allocate the township estimation of grain production to each centroid. A careful examination of Ridgeway Township revealed the land was uniformly fertile and that the grain farms were relatively of the same economic and operational character. Therefore, it seemed reasonable to distribute the grain production uniformly among the production points. Thus, each production centroid was assigned a production value of 80,700 bushels. This figure of 80,700 bushels became one of the constraints in the linear programming model.

5.2 Estimation of Grain Assembly Costs

One of the more crucial steps in this research analysis involved estimating the cost associated with transporting the grain production over the rural road system. The problem presented was to develop a methodological procedure which could be uniformly applied to any stage of development in the rural road system. Therefore, it became essential to find a common denominator upon which to derive these cost estimates. The common denominator of measure was found in the average operating speed between origin and destination points as the rural road network was developed or allowed to deteriorate. As the rural road infrastructure was improved, engineering safety standards allowed for increased speeds over the new improvements which led to decreased travel time and increased average operating speeds. Likewise, as the infrastructure deteriorated, average operating speeds fell as road conditions became poorer upon which to travel.

In order to derive a schedule of the estimated costs of the transport of grain two distinct procedural steps were involved. The first procedural step involved estimating the grain producer's transport cost. The second process was the method of obtaining the grain elevator operator's cost of transportation. Four steps were involved in determining transport operating costs for grain producers. These four steps were as follows.

5.2.1 Review of Economic/Engineering Studies

The first step involved a review of economic/engineering studies to assess their potential in helping to develop a producer's average operating cost schedule. The objective in reviewing these studies were threefold. First, the review was undertaken to determine what constituted transportation costs. This part of the review was essential in determining what elements of transport cost must be identified and measured to be useful in the investigation. The second reason for the review was to investigate how other researchers derived transportation costs. This was done to determine how grain transport costs might be established and used in this thesis. Finally, it was hoped that a relevant study might be identified which could be utilized directly in this research effort. Incorporating such an accepted cost study into this research would serve to strengthen the analysis.

5.2.2 Constituents of Operating Costs

The second step involved in estimating operating costs for this study was to determine the cost constituents of grain truck operations. Transport costs can be broken into two major cost categories: (1) fixed costs; and (2) variable costs. The fixed costs of transportation are expenditures which are independent of the operation of the vehicles used in grain movement. These costs must be met irrespective of whether the transportation function is performed. Variable transport costs are comprised of those costs which are dependent upon quantity of traffic operations. These costs move in an upward direction with increased usage of the vehicle. Several studies have identified various components of the cost structure associated with truck transportation.[1] Most cost structure studies of agricultural transport functions have identified five components of fixed costs and five components associated with variable costs. The fixed cost category of grain transport is comprised of charges for depreciation, insurance, interest on investment, licenses and taxes and miscellaneous. Depreciation reflects the decline in the truck's value over time.[2] A depreciation charge is the amount of resources which must be set aside each year in order to replace the truck at the end of its productive life. Insurance charges are the premiums which are paid by haulers to guarantee against financial losses. These losses include damage to the vehicle, vehicle commodity contents,

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[1] McBride, Glynn and Robert D. Boynton, An Analysis of the Milk Hauling Cost Structure in Lower Michigan, Agricultural Business, Research Report No. 325, East Lansing, Michigan: Michigan State University, 1976.

Kulshreshtha, Surendra N., "Cost of Grain Hauling by Farm Trucks in Saskatchewan," Agricultural Science Bulletin, Farm Management 810, Publication No. 241, Saskatoon: University of Saskatchewan, 1974.

Claffey, Paul L., Running Costs of Motor Vehicles as Affected by Road Design and Traffic, Highway Research Board, National Cooperative Highway Research Program Report No. 111, Washington, D.C., 1971.

[2] In accepted accounting practices depreciation is generally charged as a fixed cost. However, it can be argued that depreciation is comprised of two parts; first, depreciation due to the passage of time (fixed cost) and second, depreciation due to usage of the vehicle (variable cost). Here, depreciation is used as a fixed cost.

property and injury to the driver and other parties. Interest on investment is a cost associated with the repayment of any loans incurred in the purchase of the truck minus the principal payment. This is a charge for the present use of resources to be repaid in the future. Licenses and taxes are fees which must be paid to local, state and federal governmental authorities for the privilege of operating on the roads and highways. The miscellaneous category of fixed costs would include such items as depreciation on any structures used in storing the vehicles and imputed interest charges on owned capital.

The variable costs associated with grain transportation include the driver's wages, tires, fuel, repair and maintenance and miscellaneous. The wages paid to drivers are the calculated labor costs involved in hauling grain. This labor input cost for driving the grain trucks from production regions to country elevators are the driver's wages. Tire expenditures involve the cost of replacement of tires. This is similar to depreciation charges only that the tires wear out with usage over the road system. This represents the amount of resources which must be set aside for each vehicle mile traveled in order to replace the tires at the end of their productive life. Fuel costs are charges for the cost of gasoline or diesel fuel used in shipping the grain from production region to country elevators and returning. Repairs and maintenance costs include the charges for such items as tune-ups, oil changes, antifreeze and lubrications. Miscellaneous costs associated as variable include items not generally accounted for in the above discussed categories. These would include items such as batteries and wiper fluid. In estimating the operating costs of grain trucks used by producers these variable and fixed costs were accounted for in the estimation procedure.

5.2.3 Development of a Modified Cost Structure Study

In August of 1972 the Interstate Commerce Commission (ICC) undertook a large study of the cost structure involved in the transportation of freight. This study served as the foundation for developing the cost schedule used in this research. The ICC study was regional in nature, developing and reporting costs by four regions. These four regions were the Middle Atlantic, Southern, East-South and South Central. The most appropriate region to this analysis was the South Central territory which included freight movements in and among the states of Michigan, Ohio, Indiana, Illinois, Kentucky, Tennessee and Alabama. This study was based upon the individual carrier's 1973 annual reports and supplemental survey information gathered by the ICC. Supplemental statistics were required by the ICC of five major carriers in the South Central territory. These carriers were: (1) Central Motor Lines, Inc.; (2) Gordon Transport, Inc.; (3) Overland Transportation Company; (4) Pic-Walsh Freight Company; and (5) Terminal Transport Company, Inc.

Six sources of information were utilized in developing these transport cost figures. ICC forms numbered 2, 4, 7, 10 and 11 along with field reports formed the data base in the analysis. Form 2, traffic analysis, is based upon a continuous probability sample basis of intercity freight bills. These freight bills and other sources such as bills of lading provided information on freight movement, weights and type of shipments. Form 4, pickup and delivery time study, supplied pertinent information on time and motion studies used in distributing costs to pickup and delivery services. The data gathered for this form was from a probability sample basis covering 5 randomly selected days and a random selection of trips. Form 7, line-haul trip report study, was based upon a probability sample basis of a random selection of trips and a random selection of 7 days at each terminal. This provided information on such factors as length of haul, load factor, etc. A random sample of terminals combined with a random sample of all terminals on 5 days provided data for Form 10, the platform study. This was used to derive data on handling weights, costs, etc. Form 11, analysis of peddle-trip operations, was used to separate peddle operations between line-haul and pickup and delivery operations. ICC field studies and reports provided additional accounting and statistical information as needed to supplement the carriers' annual reports.

From the data collected and analyzed, the ICC was able to derive many cost components associated with truck transportation. Cost data reported included variable costs for terminals, platform handling, weight moved, pickup and delivery, etc. The cost schedule most essential to the analysis of rural road development was Appendix G's Table II, Line-Haul Costs Adjusted for Effects of Speed. The ICC, using the cost constituents identified above, derived a cost schedule based upon operating speed.

Once the usefulness of the ICC procedure was established, it became necessary to derive a method of modifying this component of the cost structure study to the needs of this research analysis. Essentially, two things had to be accomplished; the 1973 study had to be updated to 1977 and the cost schedule modified to reflect the operating cost of the much smaller 2 to 4 ton vehicles.

To update the ICC cost study to reflect the 1977 cost structure, use was made of the Consumer Price Index for transportation as reported in the <u>1978 Economic Report of the President</u>. The total line-haul cost per vehicle mile based upon the actual cost study average speed was 52.230 cents in 1973. In 1973 the transportation index was 123.8. In 1977 this index had increased to 177.2 which when applied to the 1973 cost of transportation translated into an average operating speed cost of 74.759 cents per vehicle mile. The accuracy of this derived figure was reasonably guaranteed when compared to the average operating speed cost of 75 cents per vehicle mile as reported by the American Trucking Association.

With the completion of the 1977 cost update procedure it became necessary to establish a method of modifying the ICC updated cost structure to reflect the difference in operating costs between the larger 40,000 pound vehicles in the ICC study and the 2 to 4 ton trucks used for the hauling of grain between producers and local grain elevators. After consultation with a leading expert in transportation,[3] a methodology was established which reasonably insured accurate cost information for inclusion in this research. The procedure was comprised of six steps. The first step was already accomplished by updating the average 1973 operating cost per vehicle mile to reflect 1977 costs. The second step in the analysis involved the assignment of the various costs at each operating speed. This was accomplished by distributing the 1977 cost by the same percentage factor as existed in 1973. The percentage distribution factor was defined for each operating speed as that 1973 operating speed cost divided by the average 1973 operating speed cost. The percentage distributional factor was then multiplied by the 1977 cost of

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[3]The author is indebted to Professor Donald J. Bowersox of the Department of Marketing and Transportation Administration, Michigan State University, who provided invaluable assistance in developing this methodological procedure.

74.759 cents. Since the ICC cost study was done in increments of 5 miles per hour, each unit mph was obtained through interpolation. The major difference in costs between vehicle types was due almost solely to fuel consumption rates. Therefore, the third step involved the determination of fuel rates as they existed in 1977. Since most of these vehicles operated on diesel fuel, this type of fuel cost was obtained for 1977. Data secured from the Michigan Department of Agriculture as reported in the 1978 Michigan Agricultural Statistics indicated average diesel fuel costs per gallon in 1977 was 46.8 cents as compared to 22.8 cents per gallon in 1973. Making use of information supplied by Michigan's truck dealers on the average miles per gallon obtained by the larger vehicles and the smaller 2 to 4 ton vehicles provided the needed data to complete steps 4 and 5. Step 4 involved estimating the cost per vehicle mile of diesel fuel for the larger vehicles. The large trucks averaged 4 miles per gallon which indicated a vehicle mile cost of 11.7 cents in fuel consumption (i.e., 46.8 cents/4mpg). Step 5 was designed to determine the fuel cost per vehicle mile on the smaller vehicles. These vehicles were obtaining an average 8 miles per gallon which translated into a fuel consumption cost of 5.85 cents per vehicle mile. Subtracting the two fuel consumption costs involved in steps 4 and 5 (i.e., step 4 minus step 5) provided a measure of the cost savings between the two vehicle types. Step 6 was accomplished when this cost differential was accounted for in the updated 1977 cost schedule. The schedule was modified by deducting the cost differential so that the new schedule reflected operating costs for the 2 to 4 ton grain hauling vehicles.

5.2.4 Estimation of the Average Operating Speed Cost Schedule

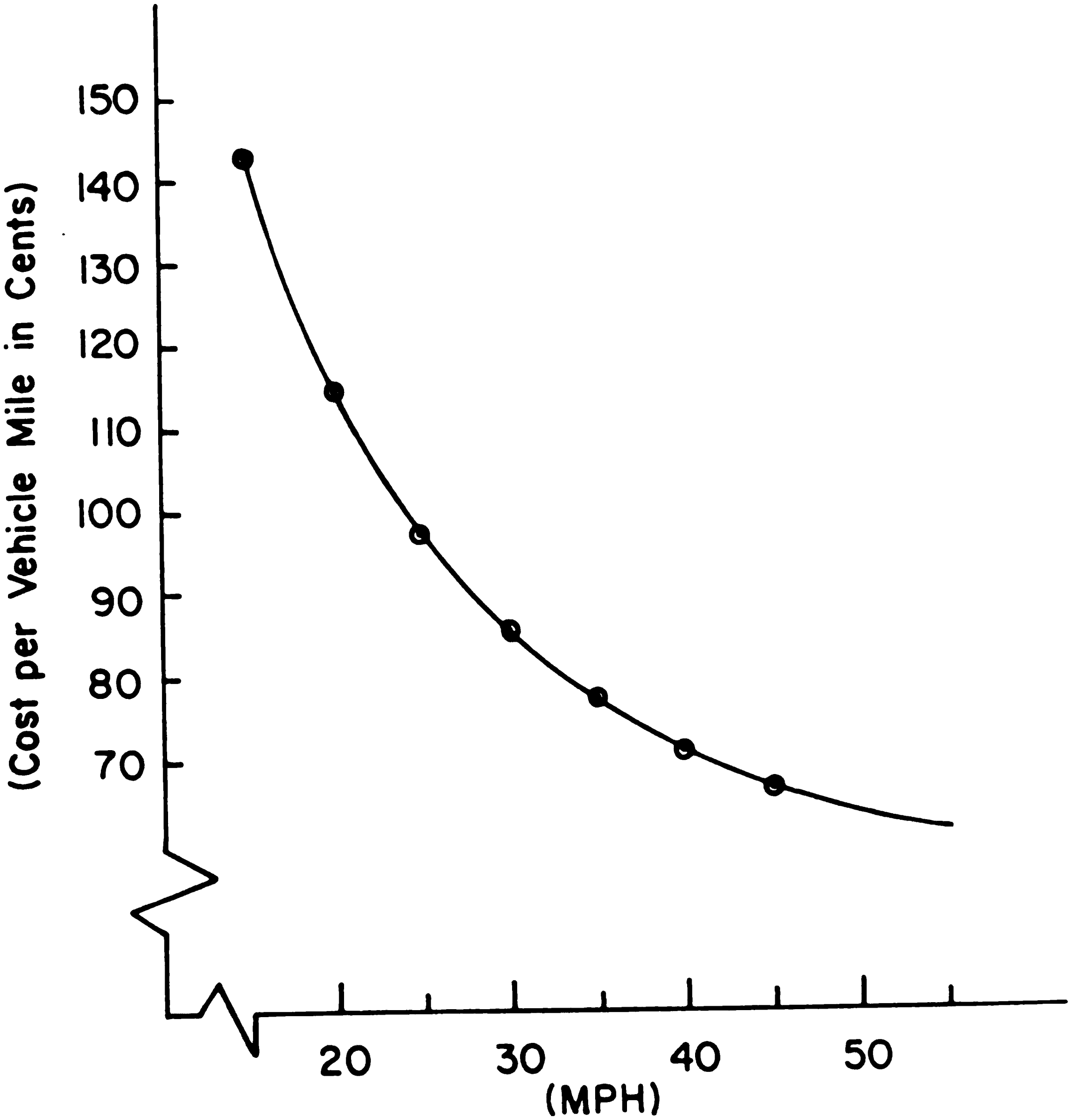
The final step was the completion of the average operating speed cost schedule utilizing a methodology developed above. A cost schedule was compiled ranging from 15 mph to the legal speed limit of 55 mph. The costs of operation at these extreme speeds was a low of 61 cents per vehicle mile at 55 mph and a high of $1.435 per vehicle mile at 15 mph (see Table 5-2). The cost schedule showed a downward sloping curve when cost is plotted as a function of operating speed (see Figure 5-1). The primary reason for the downward sloping cost curve is due to savings in wages paid as operating speeds increase. Increased operating speeds mean decreased travel time which translates into lower labor costs which is the major cost factor in transportation.

The second component of this cost structure study for the transport of grain involved estimating the costs incurred by grain elevator operators in moving grain commodities from their storage facilities to the terminal elevator located in the Toledo, Ohio area. This was necessitated by the fact that the vehicle types used in this segment of the grain marketing system were larger than those used by farmers, but smaller than those vehicles reported on in the ICC study. As indicated previously in this thesis, all the grain elevators utilized the same single-bed vehicles with a maximum capacity of 1,000 bushels when transporting their grain.

Routes chosen by the grain elevators in shipment to the Toledo area did not vary as road conditions changed except in the case of the elevator located at Jasper. Also, all elevators were located on or within easy reach of major state trunk lines and rural county primary roads. For these two reasons the cost structure did not change with differing

TABLE 5-2. 1977 Line-Haul Costs Per Vehicle Mile by Average Operating Speed for 2 to 4 Ton Grain Hauling Vehicles

Average Operating Speed (mph)	Transportation Costs (Cents Per Vehicle Mile)
15	143.469
16	137.736
17	132.003
18	126.270
19	120.537
20	114.802
21	111.357
22	107.912
23	104.467
24	101.022
25	97.575
26	95.287
27	92.999
28	90.711
29	88.423
30	86.136
31	84.496
32	82.856
33	81.216
34	79.576
35	77.936
36	76.709
37	75.482
38	74.255
39	73.028
40	71.803
41	70.852
42	69.901
43	68.950
44	67.999
45	67.048
46	66.438
47	65.828
48	65.218
49	64.608
50	64.000
51	63.400
52	62.800
53	62.200
54	61.600
55	61.000



SOURCE: Interstate Commerce Commission, <u>Cost of Transporting Freight</u>, 1973

Per Vehicle Mile Line-Haul Costs by Average Operating Speed for 2 to 4 Ton Grain Hauling Vehicles.

FIGURE 5-1

investments in the rural road infrastructure except in the case of Jasper.

In order to determine the transport cost structure associated with the 1,000 bushel capacity vehicles, a survey of all five Lenawee County grain elevators was conducted. The information secured by this method proved to be consistent among all five elevators. The survey was designed to determine the round trip cost per bushel of grain shipped from the particular grain elevator to the terminal elevator in Ohio. All five county elevators cooperated in the survey and provided information to derive the following cost structure.

Elevator Location	Rate Charges Per Bushel Per Trip
Britton	5¢
Clinton	10¢
Adrian	8¢
Blissfield	5¢
Jasper	6¢

As indicated previously, the cost structure remained unchanged throughout the analysis with the exception of the Jasper Elevator. As the road system was improved, a time savings occurred in the shipment of grain from Jasper to Toledo to warrant a 1 cent reduction in transport costs. Therefore, Jasper's transport rate was estimated at 5 cents per bushel per trip as improvements in the rural road system were made. All other investment scenarios used the survey results of 6 cents per bushel per trip.

5.3 Estimation of Costs Related to Rural Road Maintenance and Construction

To evaluate the economic consequences of various rural road investment scenarios, it is necessary to know the cost to local governments as well as the benefits and costs to grain producers. Such construction and maintenance costs are essential criteria measures against which to evaluate any benefits or costs derived through various rural road investment decisions.

Construction and maintenance costs used in this research study were derived from engineering cost studies undertaken by the Michigan Department of State Highways and Transportation, Transportation Planning Division. Based upon historical records of costs, engineering design standards and the 1974 Highway Needs Study Update, the department was able to generate annual maintenance costs per mile by surface type and number of lanes and construction costs per mile by design standard and type of construction.

Maintenance costs vary substantially depending upon the number of lanes which must be maintained, the road surface and the road type. The better the surface material comprising the roadway, the more costly it is to maintain. Likewise, as the number of lanes increase and as usage increases as portrayed through the road functional classification,[4] maintenance expenditures per mile increase. Annual maintenance costs range from as low as $945 per mile for typically two lane gravel and earthen roads to as high as $17,550 for six lane hard surface state trunk lines within urban areas. Appendix E displays the annual maintenance costs per mile by surface type, number of lanes and functional class.

Rural construction costs vary substantially depending upon the design standards and type of construction. New construction on rural

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[7]Functional classification is similar to legal systems as discussed previously in this study. Functional classifications denote road usage and jurisdictional responsibility.

roads can vary from as little as $40,800 per mile for rural local access roads to as high as $1,008,200 per mile for state trunk line rural mileage. In this particular research study the interest is in construction costs on county primary and local roads. More specifically, the interest is in the construction cost of replacing various surface types with a bituminous surface. Table 5-3 indicates the cost of construction by road type.

5.4 Summary

This chapter has been divided into three segments, each covering a specific estimation. The first segment dealt with estimating the derived demand for transportation services. This was accomplished through four steps. These steps were the selection of the production region, assignment of production centroids within the region, estimation of regional grain production and appropriation of the regional grain production to each production centroid. It was estimated that 2.1 million bushels of grain required transport from the production region in this study with each of the 26 producing units shipping 80,700 bushels of grain.

The second part of the chapter estimated the costs associated with the movement of grain. Two cost components were identified and measured. The transport cost incurred by the producer and the transport cost incurred by the grain elevator operator. The grain elevator operator's cost structure was established through a survey of all existing grain elevators within the study area. The grain producers' cost schedule was derived by modifying an Interstate Commerce Commission cost structure study of freight movement in 1973. Utilizing this study, producers' transport costs were derived as a function of average operating speed.

TABLE 5-3. Rural Road Improvement Costs by Road Type, 1977*

Road Type	Upgrade to a Bituminous Surface (Cost Per Mile)
Bituminous Surface Treated Gravel	$82,400
Gravel and Similar	$82,400
Graded and Drained Earth	$82,400
Unimproved Earth	$111,500

*Source: Michigan Department of State Highways and Transportation, Transportation Planning Division.

The final section estimated local and state government costs of maintaining and constructing the rural road system. This was accomplished by the Michigan State Department of Highways and Transportation based upon historical records of costs, engineering design standards and the <u>1974 Highway Needs Survey Update</u>.

CHAPTER VI

OPTIMAL COMMODITY FLOW AND TRANSPORT EFFICIENCY IN THE GRAIN ASSEMBLY MARKETS IN LENAWEE COUNTY

The intent of this chapter is to present the empirical findings from the computer analysis of the optimal grain commodity flow pattern and the minimum transport assembly costs associated with such grain movement. This chapter investigates the empirical results of six different investment scenarios which involve (1) maintaining the current rural road infrastructure; (2) upgrading the present rural road system; and (3) four deterioration models of the county local road network over a 5 year, 10 year, 15 year and 20 year time period. The empirical results are all recorded in constant 1977 dollars and involve 1977 production levels for ease of comparison.

6.1 Investment Scenario I

The first rural road investment scenario investigated involved assessing the economic consequences of maintaining the rural road system as it presently exists in Lenawee County. Under this investment decision it is assumed that the Lenawee County Road Commission would provide resources sufficient enough for the upkeep of the existing rural road network. The empirical results of this particular investment scenario serves as the yardstick against which the remaining five investment decisions are measured.

Based upon the computer analysis of the existing rural road infrastructure type, condition, usage and driving characteristics, determination as to the travel time and distance between each production point and local grain elevator was made. Table 6-1 displays the distance and time matrix between production units and country grain elevators. From this table it can be observed that the grain elevator located at Britton is the closest to all production points, being no farther than 8 miles from any given production centroid. Toledo is the farthest grain elevator from the producing region studied. The Toledo terminal elevator is located between 27 and 39 miles from the grain production in Ridgeway Township. Travel time involved in grain transport to any given elevator is as low as 4 minutes to Britton and as high as 48 minutes to Toledo under the existing rural road infrastructure.

Utilizing the relationship between time and distance, the average operating speed was established between each production point and each country grain elevator. Table 6-2 indicates the average travel speeds calculated. This table shows that on the poorer roads the average operating speeds were reduced drastically. The lowest average operating speed was 20 mph with many speeds found to be in the 20s. Access to major state trunk lines between production regions and grain elevators served to increase average operating speeds. The greatest operating speed was 54 mph with 15 routes between production regions and the elevator at Toledo operating at 50 mph or greater.

The transport costs per bushel of grain moved is given in Table 6-2. This was derived utilizing the transport cost schedule established in Chapter V plus costs associated with the handling of grain and the load capacity of the vehicles involved in transporting the grain commodities. Grain assembly cost from Ridgeway Township ranged from 2.2 cents per bushel to 31.5 cents per bushel.

TABLE 6-1. 1977 Rural Road Network--Distance and Time Matrix Between Production Units and Country Grain Elevators*

To / From	Time						Distance					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
	(Minutes)						(Miles)					
1	7	28	35	33	45	41	3	14	20	16	27	35
2	6	26	33	31	43	39	3	13	20	16	26	35
3	4	25	32	30	42	39	2	13	19	15	25	35
4	6	25	28	29	38	44	2	11	14	15	20	37
5	7	24	27	27	37	45	3	11	13	14	20	37
6	8	20	27	29	37	46	5	9	16	15	22	39
7	9	22	27	28	37	47	4	10	13	14	20	39
8	10	26	27	25	37	48	5	12	13	11	20	39
9	6	27	30	27	40	44	2	13	14	13	21	37
10	6	27	32	26	42	43	3	13	15	13	21	36
11	5	26	33	28	43	40	3	13	19	14	26	35
12	8	28	35	30	45	40	4	14	20	14	27	34
13	8	28	35	30	45	40	4	14	20	14	27	34
14	9	29	36	28	44	42	4	14	15	13	24	36
15	6	27	32	26	42	43	3	13	15	13	21	36
16	8	28	28	25	38	46	3	14	13	11	20	38
17	11	26	25	22	35	46	5	12	12	10	19	31
18	9	24	23	23	33	47	5	12	12	13	18	39
19	13	29	24	19	34	44	5	13	12	9	18	30
20	14	31	23	16	32	40	7	15	11	8	18	29
21	13	34	29	21	38	45	5	15	13	10	20	30
22	10	31	29	21	38	41	5	16	14	11	21	28
23	12	33	33	26	42	40	5	16	16	13	23	27
24	13	34	35	27	43	40	6	16	17	13	24	27
25	17	31	23	16	32	42	8	15	11	7	18	29
26	13	32	24	17	33	41	6	15	12	9	19	29

*Source: Michigan Department of State Highways and Transportation.

TABLE 6-2. 1977 Rural Road Network--Average Travel Speed and Cost Per Bushel of Grain Moved Between Production Units and Country Grain Elevators

To / From	Average Travel Speed (mph)						Transport Cost (Cents Per Bushel)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	26	30	34	29	36	51	3.6	15.1	19.9	17.7	25.9	27.7
2	30	30	36	31	36	54	3.2	14.0	19.2	16.9	24.9	27.0
3	30	31	36	30	36	54	2.2	14.0	18.2	16.2	24.0	27.0
4	20	26	30	31	32	50	2.9	13.1	15.1	15.8	20.7	29.6
5	26	28	29	31	32	49	3.6	12.5	14.4	14.8	20.7	29.9
6	38	27	36	31	36	51	4.6	10.5	15.3	15.8	21.1	30.9
7	27	27	29	30	32	50	4.6	11.6	14.4	15.1	20.7	31.2
8	30	28	29	26	32	49	5.4	13.6	14.4	13.1	20.7	31.5
9	20	29	28	29	32	50	2.9	14.4	15.9	14.4	21.7	29.6
10	30	29	28	30	30	50	3.2	14.4	17.0	14.0	22.6	28.8
11	36	30	35	30	36	53	2.9	14.0	18.5	15.1	24.9	27.2
12	30	30	34	28	36	51	4.3	15.1	19.9	15.9	25.9	26.9
13	30	30	34	28	36	51	4.3	15.1	19.9	15.9	25.9	26.9
14	27	29	25	28	33	51	4.6	15.5	18.3	14.7	24.4	28.5
15	30	29	28	30	30	50	3.2	14.4	17.0	14.0	22.6	28.8
16	23	30	28	26	32	50	3.9	15.1	14.7	13.1	20.7	30.4
17	27	28	29	27	33	40	5.8	13.6	13.3	11.6	19.3	27.8
18	33	30	31	34	33	50	5.1	12.9	12.7	12.9	18.3	31.2
19	23	27	30	28	32	41	6.5	15.1	12.9	10.2	18.6	26.6
20	30	29	29	30	34	44	7.5	16.6	12.2	8.6	17.9	24.6
21	23	26	27	29	32	40	6.5	17.9	15.1	11.1	20.7	26.9
22	30	31	29	31	33	41	5.4	16.9	15.5	11.6	21.3	24.8
23	25	29	29	30	33	41	6.1	17.7	17.7	14.0	23.3	23.9
24	28	28	29	29	33	41	6.8	18.1	18.8	14.4	24.4	23.9
25	28	29	29	26	34	41	9.1	16.6	12.2	8.3	17.9	25.7
26	28	28	30	32	35	42	6.8	17.0	12.9	9.3	18.5	25.3

Incorporating these transportation assembly costs into the objective function discussed in Chapter IV and utilizing the production estimates derived in Chapter V as the constraint parameters in the transportation linear programming model, the optimal commodity flow pattern and minimum aggregate transportation assembly costs were estimated. Table 6-3 indicates the optimal commodity flow pattern of grain from Ridgeway Township. The solution of the transportation linear programming problem indicated the shipment to two out of the six country grain elevators in the study. The two elevators in solution were Britton and Blissfield. Britton was located within the production region and Blissfield just to the south (see Figure 3-1). The solution to the optimal commodity flow shows that the grain elevator located at Britton is filled to capacity with the excess flowing to Blissfield. The northern half of the Ridgeway Township grain production flows to the Britton Elevator and the southern portion of the township grain production is shipped to Blissfield. The minimum aggregate transportation assembly cost of this optimal shipping pattern is $340,955.70. This translates into a per bushel cost of 16.2 cents. Appendix H provides the computer printout of the optimal solution to the linear transportation program for the existing rural road infrastructure.

6.2 Investment Scenario II

Much emphasis in the agricultural community on the subject of transportation has stressed the need for improvements in the rural road infrastructure. The second investment scenario is designed to measure the impact upon aggregate transportation assembly costs and commodity flow patterns of improving the rural road system. The type of road over which the agricultural products flow is a major determinant of transportation

TABLE 6-3. 1977 Rural Road Network--Annual Optimal Grain Commodity Flow

To / From	Grain Shipped to Toledo Via (in Bushels)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	80,700					
2	80,700					
3	80,700					
4	80,700					
5	80,700					
6	80,700					
7	80,700					
8				80,700		
9	80,700					
10	80,700					
11	80,700					
12	80,700					
13	80,700					
14	80,700					
15	80,700					
16	20,200					
17				60,500		
18				80,700		
19				80,700		
20				80,700		
21				80,700		
22				80,700		
23				80,700		
24				80,700		
25				80,700		
26				80,700		
Total	1,150,000			948,200		

marketing costs. Hard surface roads make travel easier, faster and safer. This ability to transport produce on the rural road system faster means a reduction in farm time spent in transport and a reduction in overall transport costs.

In measuring the economic returns to rural road development the improvement criteria utilized was to improve all unimproved earth, graded and drained earth, gravel and similar and bituminous surface treated gravel rural roads. The improvement consisted of resurfacing these roads with an asphalt paving of at least 1 inch in thickness. Initially, based upon all possible grain transport routes which minimized travel time between producing regions and country grain elevators, 342.6 miles of resurfacing needs were identified. Table 6-4 indicates the number of miles identified as needing resurfacing by type of road and grain destination. No earthen roads, either unimproved or graded and drained, were utilized by producers to get their crops to market. Major improvements, based upon mileage needing resurfacing, was for routes to the Blissfield Elevator. Approximately 70 miles were singled out as needing resurfacing to decrease the travel time in marketing grain. The minimum number of miles of rural roads requiring resurfacing under the investment criteria are routes serving the Clinton Grain Elevator and local producers. Just under 40 of these miles were identified as needing resurfacing.

The computer analysis involved identifying those routes which minimized the travel time between production regions and country grain elevators following improvements in the rural road system (see Table 6-5). This table also indicates the new mileage distance between producers and local grain elevators. Improvements in the rural road infrastructure does indicate a definite time savings in travel when Table 6-5

TABLE 6-4. Rural Roads Identified as Needing Resurfacing to a Bituminous Surface by Road Type and Destination, 1977*

Road Type	Miles in Need of Resurfacing						
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Total
Bituminous Surface Treated Gravel	28.6	10.2	15.6	22.5	30.1	25.3	132.3
Gravel and Similar	26.7	28.6	28.2	47.3	39.2	40.3	210.3
Graded and Drained Earth	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unimproved Earth	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Mileage	55.3	38.8	43.8	69.8	69.3	65.6	342.6

*Source: Michigan Department of State Highways and Transportation, Transportation Planning Division.

TABLE 6-5. 1977 Rural Road Network--Developed System to a Minimum of a Bituminous Surface--Distance and Time Matrix Between Production Units and Country Grain Elevators*

To / From	Time						Distance					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
	(Minutes)						(Miles)					
1	6	25	32	26	41	40	3	14	17	15	24	35
2	5	24	31	25	40	39	3	14	17	14	24	35
3	4	23	30	24	39	39	2	13	16	14	23	35
4	5	21	26	21	35	42	3	12	14	12	21	37
5	5	21	25	21	34	43	3	12	13	12	20	37
6	8	18	25	22	35	45	5	10	13	13	21	39
7	8	19	25	21	34	45	4	10	13	12	20	38
8	6	22	25	19	34	44	4	12	13	11	20	38
9	5	22	27	21	36	42	2	13	14	12	21	37
10	6	25	27	21	36	41	3	14	15	12	22	36
11	5	24	29	23	38	40	3	14	16	13	23	35
12	6	26	30	23	39	38	4	15	16	13	23	34
13	6	26	30	23	39	38	4	15	16	13	23	34
14	7	26	29	22	38	40	4	15	16	12	23	28
15	6	25	27	21	36	41	3	14	15	12	22	36
16	6	22	25	19	34	43	4	13	13	11	20	37
17	8	23	24	17	33	43	5	13	13	10	20	31
18	8	22	22	18	31	44	5	12	12	10	19	31
19	9	24	23	16	31	41	5	13	12	9	19	30
20	12	26	21	14	30	39	7	14	11	8	18	29
21	9	25	24	17	33	42	5	14	13	10	20	30
22	9	28	26	18	35	38	5	16	14	10	21	28
23	9	28	29	20	38	37	5	16	16	11	21	27
24	9	29	30	21	39	37	6	17	17	12	22	27
25	14	25	20	12	28	38	8	14	10	7	17	29
26	11	27	22	15	31	40	6	15	12	8	19	29

*Source: Michigan Department of State Highways and Transportation.

is compared with Table 6-1 under Investment Scenario I, maintaining the infrastructure as it presently exists. The distance traveled to market with the grain shows a slight difference in a few of the grain marketing routes over the existing rural road system. The minimum time involved in grain transport after improvements remains at 4 minutes, but the maximum time decreases from the original 48 minutes to 39 minutes, a savings of 9 minutes.

Table 6-6 shows the relationship between the two sets of data in the previous table. Based upon time and distance, average operating speed is determined and presented in Table 6-6. Improvements in the road surface has increased the minimum speed of 20 mph under the existing rural road system to 24 mph after improvements. The maximum speed remains at 54 mph, but three additional routes are increased to this average operating speed over existing conditions. Transport assembly costs, as presented in Table 6-6, show a decline as a result of rural road development. The new grain assembly costs from Ridgeway Township range from 2.2 cents per bushel to 30.6 cents per bushel.

The optimal commodity flow pattern and minimum aggregate transport assembly costs for grain movement after rural road development were estimated by using the township derived demand for grain transportation and the per bushel costs of transport. The results of the linear transportation programming solution are presented in Table 6-7 and in Appendix I. The solution of the linear transportation problem indicated the destination of grain shipments were unaffected by improvements. The grain marketed under the improved conditions were shipped to Toledo via the local elevators located at Britton and Blissfield. As under the existing road infrastructure, the Britton Elevator was filled to capacity

TABLE 6-6. 1977 Rural Road Network--Developed System to a Minimum of a Bituminous Surface--Average Travel Speed and Cost Per Bushel of Grain Moved Between Production Units and Country Grain Elevators

To	Average Travel Speed (mph)						Transport Cost (Cents Per Bushel)					
From	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrain	Blissfield	Jasper	Toledo
1	30	34	32	35	35	53	3.2	13.9	17.6	14.6	23.4	27.2
2	36	35	33	34	36	54	2.9	13.6	17.3	13.9	23.0	27.0
3	30	34	32	35	35	54	2.2	12.9	16.6	13.6	22.4	27.0
4	36	34	32	34	36	53	2.9	11.9	14.5	11.9	20.1	28.8
5	36	34	31	34	35	52	2.9	11.9	13.7	11.9	19.5	29.0
6	38	33	31	35	36	52	4.6	10.2	13.7	12.7	20.1	30.6
7	30	32	31	34	35	51	4.3	10.4	13.7	11.9	19.5	30.1
8	40	33	31	35	35	52	3.6	12.2	13.7	10.7	19.5	29.8
9	24	35	31	34	35	53	2.5	12.7	14.8	11.9	20.5	28.8
10	30	34	33	34	37	53	3.2	13.9	15.2	11.9	20.8	28.0
11	36	35	33	34	36	53	2.9	13.6	16.2	12.9	22.1	27.2
12	40	35	32	34	35	54	3.6	14.6	16.6	12.9	22.4	26.2
13	40	35	32	34	35	54	3.6	14.6	16.6	12.9	22.4	26.2
14	34	35	33	33	36	42	4.0	14.6	16.2	12.2	22.1	24.5
15	30	34	33	34	37	53	3.2	13.9	15.2	11.9	20.8	28.0
16	40	35	31	35	35	52	3.6	12.7	13.7	10.7	19.5	29.0
17	38	34	33	35	36	43	4.6	12.9	13.2	9.7	19.2	26.7
18	38	33	33	33	37	42	4.6	12.2	12.2	10.2	17.9	27.1
19	33	33	31	34	37	44	5.1	13.2	12.7	9.0	17.9	25.5
20	35	32	31	34	36	45	6.8	14.5	11.6	8.0	17.3	24.3
21	33	34	33	35	36	43	5.1	13.9	13.2	9.7	19.2	25.9
22	33	34	32	33	36	44	5.1	15.9	14.5	10.2	20.1	23.8
23	33	34	33	33	33	44	5.1	15.9	16.2	11.2	21.3	22.9
24	40	35	34	34	34	44	5.4	16.6	16.9	11.9	21.9	22.9
25	34	34	30	35	36	46	8.0	13.9	10.8	6.8	16.3	24.1
26	33	33	33	32	37	44	6.1	15.2	12.2	8.3	17.9	24.6

TABLE 6-7. 1977 Rural Road Network--Developed System to a Minimum of a Bituminous Surface--Annual Optimal Grain Commodity Flow

From \ To	Grain Shipped to Toledo Via (in Bushels)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	80,700					
2	80,700					
3	80,700					
4	80,700					
5	80,700					
6	80,700					
7	80,700					
8				80,700		
9	80,700					
10	80,700					
11	80,700					
12	80,700					
13	80,700					
14	80,700					
15	80,700					
16	20,200					
17				60,500		
18				80,700		
19				80,700		
20				80,700		
21				80,700		
22				80,700		
23				80,700		
24				80,700		
25				80,700		
26				80,700		
Total	1,150,000			948,200		

from the northern most producing regions while the excess southern township production was shipped to the grain elevator located at Blissfield. The minimum aggregate transportation assembly cost savings from making improvements in the rural road network was $43,820.10. This represents a cost savings of approximately 2 cents per bushel of grain moved. The total aggregate transportation assembly cost was $297,135.60.

The total mileage of rural roads needing improvement as determined from the optimal commodity flow pattern was 125.1 miles. Based upon the engineering cost studies of the Michigan Department of State Highways and Transportation, the resources needed for such an improvement was estimated at approximately $10.3 million. The life expectancy of this rural road project is estimated at 12 years. Using this life expectancy and a discount rate of 10 percent,[1] the annual resources needed for payment of the principal and interest on construction bonds for the needed improvements were approximately $1.7 million. Thus, any annual benefits from this rural road infrastructure must be evaluated with respect to at least the immediate cost of $1.7 million.

6.3 Investment Scenario III

The next set of investment decisions are based upon the assumption that limited resources for construction and maintenance will force the County Road Commission to reduce their effort in the rural road maintenance program. The most logical cuts would occur on the less frequently utilized rural roads. These rural roads are the county local roads. The third investment scenario is designed to investigate the economic

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[1]The discount rate of 10 percent was the approximate rate being paid on state and local bonds at the time of the analysis as reported in the Wall Street Journal.

consequences of allowing the county local roads to deteriorate through lack of maintenance over the next 5 years.

Based upon the computer analysis of this deterioration model's rural road infrastructure type, condition, usage, age and driving characteristics, a determination was made as to the travel time and distance involved in moving grain between each production point and local grain elevator. Table 6-8 displays the distance and time matrix between each such points. The indications from this table are that distance involved changed very little while a pronounced increase in travel time is observed in many of the grain movement routes. Although the maximum time of travel remains at 48 minutes to Toledo, the minimum travel time increases by 1 minute from 4 to 5 minutes.

Employing the relationship established between time and distance, the average operating speed and the estimated travel cost per bushel of grain moved were derived. Table 6-9 provides this data. The deterioration of the county local roads has an impact upon the grain movement in Ridgeway Township by reducing average operating speeds which, in turn, increase transport costs. The minimum average operating speed falls from 20 mph to 16 mph as a result of deterioration over a 5 year period. Maximum average speeds fall from 54 mph to 51 mph. The grain transportation assembly costs, as a result of 5 years of neglect of the county local roads, show a 1977 real cost increase.

Incorporating these new transport cost figures into the objective function to be minimized in the linear transportation model provides the solution for the 5 year deterioration investment scenario. The optimal commodity flow pattern of grain produced and transported from Ridgeway Township to Toledo, Ohio is provided in Table 6-10. The solution to

TABLE 6-8. 1982 Rural Road Network--5 Year Deterioration of the County Local Roads--Distance and Time Matrix Between Production Units and Country Grain Elevators*

To / From	Time						Distance					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
	(Minutes)						(Miles)					
1	10	31	38	36	48	44	3	14	20	16	27	35
2	7	28	34	32	44	41	3	13	20	16	26	35
3	5	26	33	31	43	40	2	13	19	15	25	35
4	6	25	28	29	38	44	2	11	14	15	20	37
5	7	24	27	27	37	45	3	11	13	14	20	37
6	8	20	27	29	37	46	5	9	16	15	22	39
7	9	22	27	28	37	47	4	10	13	14	20	39
8	11	28	29	29	39	49	3	12	13	14	20	38
9	6	27	30	27	40	44	2	13	14	13	21	37
10	6	27	32	26	42	44	3	13	15	13	21	37
11	7	28	35	30	45	42	3	13	19	14	26	35
12	10	31	36	30	46	42	4	14	16	14	23	34
13	10	31	36	30	46	42	4	14	16	14	23	34
14	12	33	37	29	46	46	4	15	16	13	24	35
15	6	27	32	26	42	44	3	13	15	13	21	37
16	8	28	38	27	38	46	3	14	13	13	20	38
17	11	27	26	24	36	48	5	13	12	10	19	31
18	9	24	23	23	33	47	5	12	12	13	18	39
19	13	31	25	19	35	44	5	14	12	9	18	30
20	14	31	23	16	32	40	7	15	11	8	18	29
21	13	34	29	21	38	45	5	15	13	10	20	30
22	10	31	29	21	38	41	5	16	14	11	21	28
23	16	37	35	27	44	42	6	16	16	13	23	27
24	15	36	35	27	43	40	6	17	17	13	24	27
25	17	31	23	19	32	43	8	15	11	9	18	30
26	13	32	24	17	33	41	6	15	12	9	19	29

*Source: Michigan Department of State Highways and Transportation.

TABLE 6-9. 1982 Rural Road Network--5 Year Deterioration of the County Local Roads--Average Travel Speed and Cost Per Bushel of Grain Moved Between Production Units and Country Grain Elevators

To / From	Average Travel Speed (mph)						Transport Cost (Cents Per Bushel)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	18	27	32	27	34	48	4.7	16.3	20.7	18.6	26.9	28.5
2	26	28	35	30	35	51	3.6	14.7	19.5	17.2	25.3	27.7
3	24	30	35	29	35	53	2.5	14.0	18.5	16.6	24.4	27.2
4	20	26	30	31	32	50	2.9	13.1	15.1	15.8	20.7	29.6
5	26	28	29	31	32	49	3.6	12.5	14.4	14.8	20.7	29.9
6	38	27	36	31	36	51	4.6	10.5	15.3	15.8	21.1	30.9
7	27	27	29	30	32	50	4.6	11.6	14.4	15.1	20.7	31.2
8	16	26	27	29	31	47	5.2	14.3	15.1	15.5	21.1	31.3
9	20	29	28	29	32	50	2.9	14.4	15.9	14.4	21.7	29.6
10	30	29	28	30	30	50	3.2	14.4	17.0	14.0	22.6	29.6
11	26	28	33	28	35	50	3.6	14.7	19.3	15.9	25.3	28.0
12	24	27	27	28	30	49	5.1	16.3	18.6	15.9	24.8	27.5
13	24	27	27	28	30	49	5.1	16.3	18.6	15.9	24.8	27.5
14	20	27	26	27	31	46	5.7	17.4	19.1	15.1	25.3	29.1
15	30	29	28	30	30	50	3.2	14.4	17.0	14.0	22.6	29.6
16	23	30	28	29	32	50	3.9	15.1	14.7	14.4	20.7	30.4
17	27	29	28	25	32	39	5.8	14.4	13.6	12.2	19.7	28.3
18	33	30	31	34	33	50	5.1	12.9	12.7	12.9	18.3	31.2
19	23	27	29	28	31	41	6.5	16.3	13.3	10.2	19.0	26.6
20	30	29	29	30	34	44	7.5	16.6	12.2	8.6	17.9	24.6
21	23	26	27	29	32	40	6.5	17.9	15.1	11.1	20.7	26.9
22	30	31	29	31	33	41	5.4	16.9	15.5	11.6	21.3	24.8
23	23	26	27	29	31	39	7.8	19.1	18.6	14.4	24.3	24.6
24	24	28	29	29	33	41	7.6	19.3	18.8	14.4	24.4	23.9
25	28	29	29	28	34	42	9.1	16.6	12.2	10.2	17.9	26.2
26	28	28	30	32	35	42	6.8	17.0	12.9	9.3	18.5	25.3

TABLE 6-10. 1982 Rural Road Network--5 Year Deterioration of the County Local Roads--Annual Optimal Grain Commodity Flow

To / From	Grain Shipped to Toledo Via (in Bushels)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	80,700					
2	80,700					
3	80,700					
4	80,700					
5	80,700					
6	80,700					
7	80,700					
8	20,200			60,500		
9	80,700					
10	80,700					
11	80,700					
12	80,700					
13	80,700					
14				80,700		
15	80,700					
16	80,700					
17				80,700		
18				80,700		
19				80,700		
20				80,700		
21				80,700		
22				80,700		
23				80,700		
24				80,700		
25				80,700		
26				80,700		
Total	1,150,000			948,200		

this transportation linear programming problem indicated grain shipment to Toledo via two local country elevators. The two elevators in solution were located at Britton and Blissfield. The optimal flow pattern indicated that little change occurred in the shipment of grain from the production regions. The Britton Elevator was filled to capacity according to the optimal solution by grain produced in the northern regions. The excess 948,200 bushels were produced in the southern regions and transported initially to the Blissfield Grain Elevator. This optimal commodity flow pattern involved a transportation assembly cost of $349,368.40. This added a transport assembly cost of $8,412.70 to the grain producers' cost schedule, or slightly more than 0.4 cents per bushel of grain moved. Appendix J provides the computer printout of the optimal solution to the linear transportation programming problem for a 5 year deterioration of the rural county local road system.

6.4 Investment Scenario IV

The fourth investment scenario is similar to the investment decision previously discussed. Under this investment decision it is assumed that resources are limited to such an extent that the County Road Commission is forced to eliminate all maintenance and construction on the county local roads under their jurisdiction. This moratorium on maintenance and construction is over a 10 year period.

The computer analysis of this 10 year deterioration model's rural road structure type, condition, capacity, age and driving characteristics indicated a further substantial loss in travel time as speeds must be reduced to accommodate highway safety engineering standards. Table 6-11 presents the distance and time matrix between each producing region and

TABLE 6-11. 1987 Rural Road Network--10 Year Deterioration of the County Local Roads--Distance and Time Matrix Between Production Units and Country Grain Elevators*

To / From	Time (Minutes)						Distance (Miles)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	10	31	38	36	48	44	3	14	20	16	27	35
2	7	28	34	33	44	41	3	13	20	16	26	35
3	5	26	33	31	43	40	2	13	19	15	25	35
4	7	25	31	32	41	45	3	11	14	14	20	37
5	10	25	28	30	38	48	4	11	13	14	20	39
6	11	23	39	33	39	48	5	9	16	14	22	39
7	11	25	30	31	40	49	4	10	13	14	20	39
8	12	28	39	30	39	50	5	12	13	14	20	39
9	9	29	36	30	46	47	2	13	19	13	26	37
10	8	28	35	27	44	46	3	13	16	13	24	37
11	7	28	35	33	45	42	3	13	19	14	26	35
12	10	31	38	36	48	42	4	14	20	17	27	34
13	10	31	38	36	48	42	4	14	20	17	27	34
14	13	34	41	34	51	47	4	14	21	13	27	36
15	8	28	35	27	44	46	3	13	16	13	24	37
16	10	31	32	30	42	48	3	12	13	13	20	38
17	13	29	27	28	37	51	5	13	12	10	19	40
18	9	24	23	24	33	47	5	12	12	12	18	39
19	18	33	28	23	38	47	7	14	12	9	18	30
20	14	31	23	16	33	40	7	15	11	8	19	29
21	15	36	29	21	38	45	6	17	13	10	21	30
22	10	31	29	21	38	41	5	16	14	11	22	28
23	17	37	35	28	45	42	7	17	16	13	24	27
24	17	38	36	28	45	41	8	18	17	13	25	27
25	18	32	24	20	34	44	8	15	11	9	19	30
26	13	32	24	17	34	41	6	15	12	9	20	29

*Source: Michigan Department of State Highways and Transportation.

each country grain elevator. The travel time involved ranged from 5 minutes for a 2 mile trip to 51 minutes for a 40 mile trip.

Table 6-12 displays the results of the 10 year deterioration of the county local roads on average travel speeds and transportation assembly costs for grain movement in Ridgeway Township. As can be seen from this table, the average operating speed is reduced from 20 mph to 13 mph on the low end of the average speed spectrum and from 54 mph to 53 mph on the high end. The cost of performing the transportation assembly function is substantially increased when the local county roads are allowed to deteriorate.

Utilizing these derived transportation assembly costs directly in the objective function which is to be minimized and the production estimates requiring transport services, the optimal solution is obtained. The optimal solution to the 10 year deterioration scenario of the linear transportation problem is presented in Appendix K. The optimal solution of grain movement is undertaken at a cost of $360,303.20. This is an added cost of $19,347.50 to the grain marketing system. This represents approximately 0.9 cents per bushel in additional marketing costs. The optimal commodity flow pattern of grain produced in Ridgeway Township is presented in Table 6-13. The optimal solution to the linear transportation problem indicates that to minimize costs, grain shipments to Toledo must occur via two local grain elevators. The two grain elevators in solution were located at Britton and Blissfield. The optimal flow pattern indicated very little change in grain movement occurring over the rural road infrastructure. The optimal solution filled the Britton Elevator to capacity with 1,150,000 bushels of grain. The production source of grain flowing to Britton occurred from producing regions

TABLE 6-12. 1987 Rural Road Network--10 Year Deterioration of the County Local Roads--Average Travel Speed and Cost Per Bushel of Grain Moved Between Production Units and Country Grain Elevators

To / From	Average Travel Speed (mph)						Transport Cost (Cents Per Bushel)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	18	27	32	27	34	48	4.7	16.3	20.7	18.6	26.9	28.5
2	26	28	35	29	35	51	3.6	14.7	19.5	17.7	25.3	27.7
3	24	30	35	29	35	53	2.5	14.0	18.5	16.6	24.4	27.2
4	26	26	27	26	29	49	3.6	13.1	16.3	16.7	22.1	29.9
5	24	26	28	28	32	49	5.1	13.1	14.7	15.9	20.7	31.5
6	27	23	33	25	34	49	5.8	11.8	16.2	17.1	21.9	31.5
7	22	24	26	27	30	48	5.4	12.6	15.5	16.3	21.5	31.8
8	25	26	27	28	31	47	6.1	14.3	15.1	15.9	21.1	32.1
9	13	27	32	26	34	47	3.8	15.1	19.7	15.5	25.9	30.4
10	23	28	27	29	33	48	3.9	14.7	18.6	14.4	24.4	30.2
11	26	28	33	25	35	50	3.6	14.7	19.3	17.1	25.3	28.0
12	24	27	32	28	34	49	5.1	16.3	20.7	19.3	26.9	27.5
13	24	27	32	28	34	49	5.1	16.3	20.7	19.3	26.9	27.5
14	18	25	31	23	32	46	6.3	17.1	22.2	17.0	38.0	29.9
15	23	28	27	29	33	48	3.9	14.7	18.6	14.4	24.4	30.2
16	18	23	24	26	29	48	4.7	15.7	16.4	15.5	22.1	31.0
17	23	27	27	21	31	47	6.5	15.1	13.9	13.9	20.1	32.9
18	33	30	31	30	33	50	5.1	12.9	12.7	12.9	18.3	31.2
19	23	25	26	23	28	38	9.1	17.1	14.3	11.8	20.4	27.8
20	30	29	29	30	35	44	7.5	16.6	12.2	8.6	18.5	24.6
21	24	28	27	29	33	40	7.6	19.3	15.1	11.1	21.3	26.9
22	30	31	29	31	35	41	5.4	16.9	15.5	11.6	21.4	24.8
23	25	28	27	28	32	39	8.5	19.3	18.6	14.7	24.9	24.6
24	28	28	28	28	33	40	9.1	20.4	19.3	14.7	25.4	24.2
25	27	28	28	27	34	41	9.3	17.0	12.5	10.5	18.9	26.6
26	28	28	30	32	35	42	6.8	17.0	12.9	9.3	19.5	25.3

TABLE 6-13. 1987 Rural Road Network--10 Year Deterioration of the County Local Roads--Annual Optimal Grain Commodity Flow

To / From	Grain Shipped to Toledo Via (in Bushels)					
	Britton	Clinton	Adrian	Blissfield	Jasper	Toledo
1	80,700					
2	80,700					
3	80,700					
4	80,700					
5	80,700					
6	80,700					
7	80,700					
8				80,700		
9	80,700					
10	20,200			60,500		
11	80,700					
12	80,700					
13	80,700					
14	80,700					
15	80,700					
16	80,700					
17				80,700		
18				80,700		
19				80,700		
20				80,700		
21				80,700		
22				80,700		
23				80,700		
24				80,700		
25				80,700		
26				80,700		
Total	1,150,000			948,200		

in the northern half of Ridgeway Township. The excess production of 948,200 bushels produced primarily in the southern half of the production region were destined to Blissfield.

6.5 Investment Scenarios V and VI

Investment Scenarios V and VI were intended to investigate the economic impacts to grain producers and local grain elevators as the rural road infrastructure was allowed to deteriorate further over a 15 year and 20 year time period, respectively. Because of the characteristics of the roadway surface and the expected usefulness of them, it was discovered that all the deterioration that would occur in the 15 to 20 year span would have already occurred over the first 10 years according to the model employed by the Department of State Highways and Transportation. The network model did not allow for deterioration beyond a 10 year level. Therefore, the time and distance matrix, average operating speeds and transportation assembly costs would remain the same as under Investment Scenario IV. The optimal solution to the linear transportation programming problem would be identical to that secured under the investment decision to reframe from maintenance and construction expenditures on the county local road system over a 10 year time horizon. The reader is therefore referred to Investment Scenario IV for a discussion of the results and consequences of not maintaining the county local rural road system over a 15 year and 20 year time period.

6.6 Summary

This chapter has presented the empirical findings from the computer analysis of six different investment scenarios. The research investigated three general classes of investment decisions: (1) maintenance of existing rural road infrastructure; (2) improvements in the present rural road system; and (3) deterioration in the rural road network. The empirical findings indicate that improvements in the rural road structure through resurfacing of earthen, gravel and tar-sprayed roads do lead to decreased travel time and decreased costs of grain transport. Such improvements reduce transportation assembly costs in grain by approximately 2 cents per bushel, but at an annual cost of $1.7 million. Based upon 1977 grain production levels, this translated into an aggregate transport cost savings of $43,820.10. The analysis showed that allowing the county local roads to deteriorate placed added costs on grain producers. Through a lack of maintenance and construction expenditures (assumed to be necessitated by budget cutbacks) over a 5 year and 10 year period, transportation assembly costs were increased by 0.4 cents per bushel and 0.9 cents per bushel, respectively. Further, lack of maintenance programs on county local roads over a 15 and 20 year time period failed to show any additional cost to transportation assembly costs beyond the 0.9 cents per bushel.

The commodity flow pattern displayed a constant level of performance. Solution to the linear transportation programming problem under each investment scenario indicated the optimal commodity flow of grain to the terminal elevator in the Toledo, Ohio area was via local grain elevators located at Britton and Blissfield. In all solutions the Britton capacity of 1,150,000 bushels was reached by predominately grain production from the northern portion of the producing region. The southern producing region shipped their 948,200 bushels to the elevator at Blissfield. While the intermediate and final destinations of grain showed no variation among the different investment scenarios, the physical routes taken by producers did change as the rural road infrastructure was improved or allowed to deteriorate.

Table 6-14 summarizes the commodity flow pattern and aggregate and per bushel costs of transport associated with each investment scenario investigated.

TABLE 6-14. Empirical Results of the Linear Programming Transportation Model, Commodity Flow, Aggregate Transportation Assembly Cost and Cost Savings

Scenario	Total Grain Moved to (Million Bushels)		Aggregate Transportation Assembly Cost ($)	Cost Savings from the Existing Network	
	Britton	Blissfield		Aggregate ($)	Per bu. (¢)
I	1,150	0.948	340,955.70	-	-
II	1,150	0.948	297,135.60	43,820.10	2
III	1,150	0.948	349,368.40	(8,412.70)	(0.4)
IV	1,150	0.948	360,303.20	(19,347.50)	(0.9)
V	1,150	0.948	360,303.20	(19,347.50)	(0.9)
VI	1,150	0.948	360,303.20	(19,347.50)	(0.9)

CHAPTER VII

RURAL ROAD DEVELOPMENT IMPACTS, IMPLICATIONS AND NEEDED RESEARCH

In Chapter VI the empirical findings of this research analysis were presented. Findings were presented concerning the optimal solution for commodity flow patterns of grain and the associated minimum aggregate transportation assembly costs. The purpose of this present chapter is to present and analyze these findings with respect to the impacts and implications for the agricultural community. Specifically, it is the intent to focus upon the economic impacts of rural road development and their associated implications for the grain marketing system. As in much research, additional questions arise beyond the original question(s) analyzed which deserve further investigation. This analysis is no different. Therefore, another important purpose of this chapter is to explore some of the important remaining areas of research. In this chapter an attempt is made to suggest possible avenues for investigating these questions. The chapter is divided into two major parts. The first is a discussion of the impact upon the grain marketing system of public decisions to invest in the maintenance and/or improvement of the rural road infrastructure or public decisions to allow selected deterioration of the system. It is designed to measure the economic benefits and costs to the economic actors within the grain marketing system. A discussion centered around the implications of these decisions will be analyzed. The second major division of this chapter is designed to outline the areas of needed research. An analysis of the questions raised by this thesis and potential approaches to their solution will be presented.

7.1 Impacts and Implications

In this study an investigation has been conducted into the economic impact of rural road development on transportation assembly costs in agriculture. The research was initially designed to investigate or test the hypothesis that improving the rural road infrastructure would lead to significant economic impacts upon agriculture and conversely a deterioration of the system would lead to severe economic consequences. Investigating this question has lead to seven major findings. The following presents a listing and discussion of the major findings of this research.

7.1.1 Grain Production Alone Cannot Justify Increased Investment in the Rural Road Infrastructure

When examining the immediate economic benefits and costs from the present relative cost structure between transportation assembly costs and the cost of rural roads, it is apparent that grain production in this case study alone cannot justify increased investment in the rural road infrastructure. A careful examination of this cost structure reveals that public decisions to improve the rural road system does lead to an economic gain for the agricultural community. As presented in Chapter VI, the direct economic benefit to grain producers in reduced transportation assembly costs from rural road development totaled \$43,820.10. This \$43,820.10 is a measure of the worth to local grain producers of improvements in the rural road infrastructure. As such, this is a measure of the maximum amount that grain producers would be willing to pay for the improvements. However, to obtain this \$43,820.10 in benefits, the public through the County Road Commission must make an annual outlay of $1.7 million. The economic benefit to grain producers is sufficient enough to pay for only 3 miles of the needed 125 miles of improvements. Conversely, the incremental economic cost savings of $8,412.70 and $19,347.50 to grain producers as a result of 5 years and 10 years of county local road deterioration, respectively, is relatively small compared to the cost reduction in maintenance. Implications which can be drawn from these public decisions to improve the rural road system or maintain them as is the current policy seems to be one of two inferences. Either other users of the infrastructure derive sufficient benefits to justify the public decision for maintenance and construction, or agriculture (and other users of the rural road system) are being indirectly subsidized with public funds.

7.1.2 Improvements and/or Deterioration in the Rural Road Infrastructure has Little or No Effect Upon the Marketing Flow Pattern of Grain

The second major finding to come from this research concerns the optimal commodity flow pattern of grain. In this particular case study, it appears that the optimal commodity flow of grain is independent of improvements or deterioration in the rural road infrastructure. As changes in the rural road system were allowed to evolve, aggregate grain movements remained constant. Grain production nearest the Britton Elevator, that is the northern portion of the producing region, was shipped to that elevator while the remaining southern production was shipped southward to Blissfield. This flow pattern, it is estimated, remained constant because of three factors. The first factor deals with the location of grain elevators. The country local grain elevator is generally located on a major state trunk line which provides ease of access to the facility and allows easier shipment from the facility. Second, the physical distribution of types of rural roads is fairly uniform throughout the total road infrastructure as a result of past investment decisions. These past decisions as to the mix of rural road types may have influenced the flow pattern at that time (or the flow pattern may have determined the road mix), but it appears further investment decision will have little impact. Third, the method of improvement and deterioration in the analysis could have accounted for part of the results. Improvements and deterioration were allowed to occur at a uniform rate on all roads. If uniform improvements and/or deterioration were removed from the analysis and selective development or deterioration were analyzed, possible changes might have been observed in this optimal flow pattern.

The optimal flow pattern direction did confirm the current actual practice used in Michigan grain movement. The grain movement in Michigan is generally in a southeast direction. The optimal solution of the linear transportation model indicated this movement to be the most efficient. Therefore, one can derive the conclusion that Michigan's grain movement tends to be efficient.

The implications which can be gathered from this finding relate to the local grain elevators. It appears that the country grain elevator operators and management have very little vested interest in rural road development except as it directly affects their transportation costs. Since most elevators are on or within close access to major hard surfaced roads, transport costs for them will show very little change as a result of development or deterioration in local county roads.

7.1.3 Improvement and/or Deterioration in the Rural Road Infrastructure--Impact Upon Producers More Than Local Country Elevators

This research finding is a corollary derived from the previous discussion concerning the implication of the optimal commodity flow pattern of grain. This impact can be readily observed if an examination of the location of each economic entity is made. Producers are numerous and are located throughout the county. The infrastructure upon which many of these producers are located are nonsurfaced. That is, they consist of gravel and similar material or tar-sprayed surfacing. These are the road types which were improved under Investment Scenario II as discussed in Chapter VI. Thus, it is apparent that improvements in this rural road infrastructure would benefit those producers located upon them which must ship their grain to market over this road system. Likewise, many of these rural roads are classified as county local roads. In the deterioration models it was these local roads which received no maintenance or construction resources. Therefore, one would expect a detrimental effect upon those users of these local county roads.

By contrast, the local grain elevators are few in number and are selectively located to take advantage of the transportation system. The local grain elevators are located on the major state trunk lines which are comprised of asphalt or concrete surfaced roads and highways. This system is already fully developed based upon the present transportation demand structure for them. Since these roads and highways are economically important links in the total state infrastructure, maintenance becomes important. The local grain elevators are linked by this developed system to the terminal elevators at Toledo which produce the most economically efficient route in grain movement between them. The size of the trucks utilized in grain hauling by the grain elevators also dictates that elevators must be located on or near developed road systems. The rural roads upon which many of the producers are located cannot sustain these heavy of truck weights over a prolonged period of time. Thus, any budgetary cutbacks which might be necessary will not likely affect maintenance programs on these roads and highways. Improvement and deterioration as investigated in this research showed no impact upon the grain elevator operations which were in the solution of the linear transportation programming problem.

The implications for this finding indicates that grain elevator operators are unlikely to support programs of rural road investment. The only economic gains which the elevator operators or mar[illegible] might realize is if they could exploit the lower cost structure [illegible] the producer by offering lower prices for the grain at the elevator. However, this would seem highly unlikely since farmers would respond by trucking to the Toledo area if local prices were too low.

7.1.4 Rural Road Conditions Do Affect the Transport Cost Structure of Grain Movement

A finding of this research tends to support the contentions of authors such as Riorden[1] and the Transportation Research Board[2] that road surface affects the cost of transportation. The affects of road type, surface, grade, etc., has long been recognized as a determinant in vehicle operating costs which must be considered in estimating the benefits

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[1]Riorden, E.B., "Spatial Competition and Division of Grain Receipts Between Country Elevators," M.S. Thesis, University of Manitoba, 1965.

[2]Transportation Research Board, Cost-Benefit and Other Economic Analyses of Transportation, Transportation Research Record 490, Washington, D.C., 1974, p. 64.

of transportation projects. This research has demonstrated that operating speed characteristics are a function of the road surface and that transport costs are a function of operating speed. Improvements in the rural road system produced a transport cost savings of 2 cents per bushel over the existing rural road infrastructure. Deterioration in local county road conditions added from 0.4 cents per bushel to 0.9 cents per bushel to the cost structure involved in grain marketing transportation costs. The major cost component in the transportation cost structure which is affected by road surface appears to be labor operating costs.

7.1.5 Grain Transport Routes Will Change to Take Advantage of Improvements in the Rural Road Infrastructure

The computer mapping of routes chosen as a result of improvement and deterioration in the rural road network showed a change over the route under the existing rural road infrastructure. To optimize the flow of grain, producers will seek out those routes which will minimize the time and distance involved in hauling their product to market. As changes in the system evolve, the time and distance relationships among the various segments in the rural road system change. This changing relationship produces new routes to be considered in transporting grain. The transport efficient producer will consider these changes and establish a flow pattern for his grain which minimizes such time and distance under the new constraints.

Improvements or deterioration in the physical transport system may induce producers to create new private accesses from producing units to the improvements or away from the deteriorated portions of the system. While there is no empirical support for this implication, it is an option for those producers whose fields are bounded by two or more public roadways.

7.1.6 Economies of Scale Exist in the Transportation of Grain

Economies of scale are said to exist when a production function experiences an increased output, but on a lower point in the cost relationships being investigated. Another finding of this research seems to imply that there exists some economy of scale in the transportation function for grain movement. The relevant cost schedule to which this statement refers is both the total and variable transportation cost curves.

The empirical finding of this research analysis concerning the cost schedules for truck transportation displays the property of economies of scale. As larger vehicles were utilized in the hauling of grain, a lower per unit cost was observed. At the average operating speed of 40 mph it was observed that the smaller vehicles carrying 160 bushels of grain were operating at an average total cost per bushel, per vehicle mile of 0.45 cents. The larger 1,000 bushel capacity vehicles were operating at an approximate 0.2 cents per bushel, per vehicle mile at an average speed of 40 mph.

The major relevance of this finding pertains mostly to local grain elevators for two reasons. First, the larger volume of grain shipped at one time would allow for the local elevators to realize these economies of scale. Second, the road and highway infrastructure on which the local elevators operate in transporting grain is designed to handle the larger vehicles. For the above stated reasons, producers may not be able to realize these economies of scale. While volume of grain produced may be sufficient to warrant larger vehicles, the road structure is not designed to allow for a sustained flow of larger grain haulers in the areas of grain production.

7.1.7 Standing Operating Procedures Serve as Guides to Expenditures for Rural Road Maintenance and Construction Programs

A finding of this research thesis concerned the institutions through which resources were made available for local maintenance and construction programs. The major source of local transportation funding comes from the Michigan Transportation Fund. Initially, the State of Michigan distributes these resources based upon a complex distributional formula which takes into account such factors as population, mileage of roads, vehicle and fuel taxes collected, etc. The final distribution of these funds between maintenance and construction projects is made by the County Road Commission. In researching the method of financing it was learned that most County Road Commissions use an established operating procedure or "rule-of-thumb" in determining the distribution of resources. Generally, the institutional rules dictated a set percentage of receipts to be used in maintenance and the remaining in construction programs based upon a matching formula with the various townships. Maintenance projects were generally ranked as to importance and funding provided on a priority basis until resources ran out. Construction funds were provided on a first come, first serve basis in conjunction with the local township authorities.

These sections have examined seven major findings of this research thesis. The analysis of rural road development presented in this research is only a beginning in the understanding of the importance of rural roads. The research presented here is only a partial analysis of rural road impacts. Further studies must be initiated to determine the impacts of rural road development on other activities than those of grain movement. Additional benefits and costs are derived from the development of the rural road infrastructure which must be accounted for. A partial listing might include such benefits as: (1) reduced property damage and insurance premiums due to faster response time by local fire departments; (2) crime prevention benefits due to faster response time by local law enforcement agencies; (3) savings in commuting and other travel time, etc. A partial listing of costs might include: (1) promotion of urban sprawl; (2) traffic congestion; (3) noise pollution, etc.

Additional issues are raised by decisions to improve the rural road system which might produce negative effects. Improvements in the rural road system may help increase the rate of fuel consumption by allowing for greater operating speeds. The question then becomes, with the current "energy crisis," is this a wise policy to follow? The analysis has identified very little support for rural road development other than that on the part of the agricultural producers. Yet, funds are continually channeled into the rural areas' transportation infrastructure where perhaps the benefit/cost ratio is less than 1. The question must be raised as to why does such investment occur if, in fact, this is the case? In concluding these findings, very little can be said with respect to the total policy issue of rural road development or deterioration because all the facts are not yet accounted for. Hopefully, this analysis is a beginning in that direction and will lead to more informed policy decisions on rural road development.

7.2 Needed Research

This research effort has attempted to evaluate the economic consequences of rural road development on the agricultural community. As the investigation proceeded, additional questions and policy issues emerged. As each additional finding and its implications were revealed, it produced new questions and avenues to be explored if one is to obtain a deeper and richer appreciation of the policy issues involved in rural road development. The questions and policy issues raised were numerous. Presented below are discussions of some of the major areas of needed research.

7.2.1 What Impact Does Energy Prices Have on Rural Road Development?

An immediate area of research which comes to mind is the energy issues involved in transportation. An important component of the cost of transport involves the cost of energy in the form of fossil fuel. An increase in diesel fuel and gasoline costs have a direct effect upon the grain transport cost which producers must absorb in marketing their grain. Besides the fossil fuel costs, increased energy costs influence the production of the vehicles themselves and the cost of maintaining and constructing the rural road system. It is unclear as to how these relative price changes would affect the issue of rural road development. Therefore, an important area of research with regard to transportation in general and rural road and agricultural transport in particular is the area of energy prices and pricing policy.

7.2.2 How Do Changing Grain Prices Affect the Utilization of the Transport System?

Another area of possible fruitful research involves the investigation of relative prices of rural roads and grain. The decisions involving storage of grain and their shipment to various elevators are partially determined by the pricing structure. It would be helpful to know how the price of grain effects the movement of these commodities over the rural road system and what impact this has upon the transportation network.

7.2.3 What is the Optimal Transport Structure?

It appears from the number of roads in existence and the high cost involved in maintaining the rural network that the system is experiencing decreasing returns to further development. An important and interesting area of further research would involve determining the optimal transport structure. That is, what is the optimal road mileage necessary to accommodate the transportation needs of the rural areas? It is the author's contention that this question might be investigated by the use of linear programming techniques developed by either Stollsteimer[3] or King and Logan.[4] Presented in graphic form here is a model of how such an investigation might be used.

From Figure 7-1 it can be observed that three costs are involved. The total transport cost (TTC), the cost of maintenance and construction on the road system (MCC) and the total system cost (TSC) which is the summation of the two TTC and MCC cost curves. The objective function would be a cost function for rural roads which would be minimized in the linear program employed. In Figure 7-1 the linear programming solution would indicate that X mileage of roads within a specific configuration should be produced and maintained which would minimize the total system costs involved. Perhaps this analysis would provide the incentive to look at the potential for rural road abandonment.

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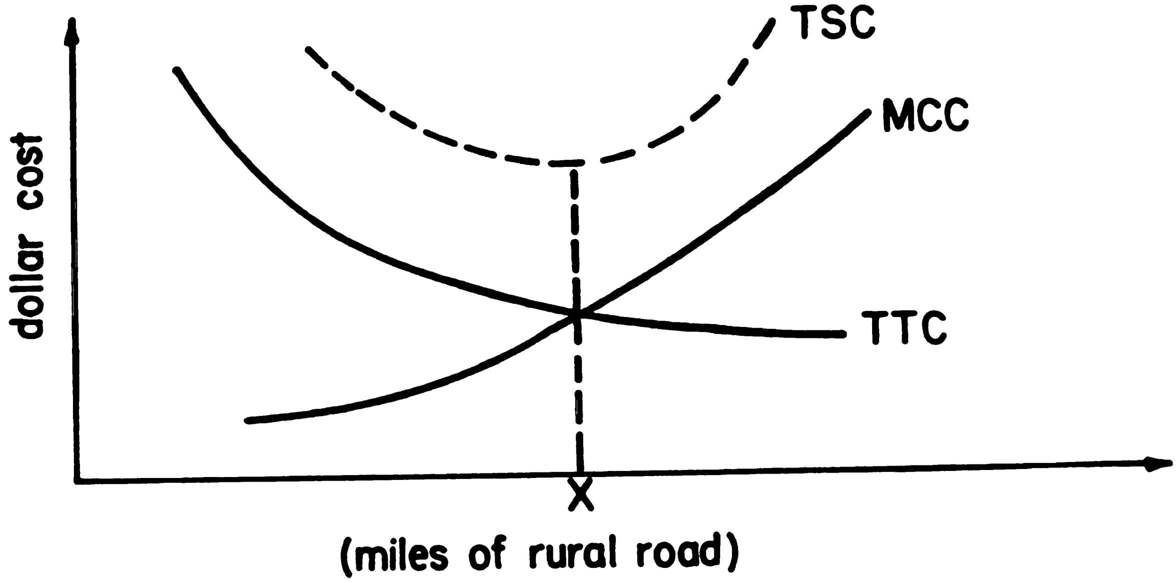
[3]Stollsteimer, J., "A Working Model for Plant Number and Locations," Journal of Farm Economics, August 1963, pp. 631-645.

[4]King, Gordon A. and S.H. Logan, "Optimum Location, Number and Size of Processing Plants with Raw Product and Final Product Shipment," Journal of Farm Economics, Vol. 46, No. 1, February 1964, pp. 94-108.



Determination of the Optimal Number of Rural Road Mileage

FIGURE 7-1

APPENDIX A

MICHIGAN HIGHWAY NEEDS

7.2.4 What is the Optimal Use of the Limited Resources for Transportation Maintenance and Construction on the Rural Road Infrastructure?

Local communities are experiencing a declining real revenue base support for transportation. Inflation has significantly increased the cost of maintenance and construction. Transportation cutbacks are occurring in the rural areas. These realities have made it more important to insure that the limited resources available to rural areas for transportation be utilized efficiently. It is proposed that further study be made on ways in which local resources may be more effectively utilized and that barriers to efficient use of resources be identified (e.g., equating marginal cost equals marginal benefit from all transport modes).

7.2.5 How Do Improvements and/or Deterioration in the Rural Road Infrastructure Affect Other Activities?

This is a recommended direct extension of this research effort. This research has shown the economic impact which accrues to grain producers as a result of rural road development and deterioration. In order to fully evaluate the consequences of improvement or deterioration in the rural road infrastructure, all benefits and costs must be accounted for. The general methodological approach used in this thesis could be employed in evaluating the economic benefits of other users of the system. Savings in commuting time or other travel time such as for social, medical and other purposes could be evaluated through the computer analysis used in this research and the appropriate value of time applied to the time savings. This approach would provide the value of travel time for people oriented movement which would be added to the agricultural benefits.

The immediate problem in this evaluation is lack of data. Very little data is currently available on origins and destinations of people traffic in the rural areas. What information is currently available consists generally of automobile counts on various segments of roads. This provides information on how many vehicles pass a certain point, but does not tell where they came from or where they were destined. What origin and destination data there is available is primarily for larger urban areas. Thus, to accomplish this research, the analyst would have to conduct, it is estimated, a 3 to 4 month survey of the travel patterns of the residents and tourists in this researcher's study area. Other benefits and costs, however, are outside the scope of this model and would have to rely upon conventional cost/benefit analysis methods for measurement.

7.2.6 What Affect Does Transportation Have on Land Values and Locational Rents?

Transportation has played a large role in the development of land uses. The provision or lack of transportation services have significant impact upon land values and their resultant uses. It is not clear as to what impact such decisions to invest in transportation has for those located on or close to the system. A quantitative investigation of land value impacts as a result of improvements in the transportation infrastructure would be a valuable contribution to the transportation decision making process. One methodological approach which might prove rewarding is the use of econometric analysis where land values are regressed against such variables as transportation expenditures, population densities, etc.

7.2.7 Other Research Questions

There are numerous other transportation related questions which are suggested by this research analysis. Included areas deserving consideration for further research are the following questions:

(1) What effect does the railroads (e.g., rail abandonment) have on rural road usage and costs?

(2) How does varying transport modes affect the transportation cost structure as development and/or deterioration occur in the rural road infrastructure?

(3) Is there another alternative to rural road development such as a subsidy to the railroads?

(4) What are the institutions involved in rural road maintenance and construction and how do they function?

(5) Is agriculture being subsidized by the public through rural road maintenance and construction programs?

(6) What affect does projected demand for transportation services have over the next several years on rural road needs?

7.3 Summary

This chapter was intended to analyze the empirical findings with respect to their impact and implications for the agricultural community. Seven major findings were observed in this analysis. These findings were:

(1) Grain transport alone cannot justify increased investment in the rural road infrastructure.

(2) Improvements and/or deterioration in the rural road infrastructure has little or no effect upon the marketing flow pattern of grain.

(3) Improvement and/or deterioration in the rural road infrastructure have a greater impact upon producers than local country elevators.

(4) Rural road conditions do affect the transport cost structure of grain movement.

(5) Grain transport routes will change to take advantage of improvements in the rural road infrastructure.

(6) Economies of scale exist in the transportation of grain.

(7) Standing operating procedures serve as guides to expenditures for rural road maintenance and construction programs.

This research effort has raised additional questions beyond that which it was originally designed to address. The questions and policy issues which are raised by this research thesis are numerous. Presented below is a list of some of the questions and policy issues raised:

(1) What impact does energy prices have on rural road development?

(2) How do changing grain prices affect the utilization of the transport system?

(3) What is the optimal transport structure?

(4) What is the optimal use of the limited resources for transportation maintenance and construction on the rural road infrastructure?

(5) How do improvements and/or deterioration in the rural road infrastructure affect other activities?

(6) What affect does transportation have on land values and locational rents?

(7) What affect do the railroads have on rural road usage and costs?

(8) How do varying transport modes affect the transportation cost structure as development and/or deterioration occur in the rural road infrastructure?

(9) Is there another alternative to rural road development such as a subsidy to the railroads?

(10) What are the institutions involved in rural road maintenance and construction and how do they function?

(11) Is agriculture being subsidized by the public through rural road maintenance and construction programs?

(12) What affect does projected demand for transportation services have over the next several years on rural road needs?

Michigan Highway Needs

EXISTING ROADWAY PROJECT

Field Data ________ Date ________

Office Data ________ Date ________

Review ________ Date ________

Road Name ________

From: ________

To: ________

IDENTIFICATION

1. Type Work Sheet — 1
2. Highway District (For State Use Only)
3. County Code
4. Place Code
5. Route Designation 1-U.S. 2-Mich. 3-County 4-Unmarked
6. Route Number (Optional For County and Municipal)
7. Project Identification

SYSTEM CLASSIFICATION

CLASS	Ru	Ur		Ru	Ur
Statewide Arterial	02	12	Primary Collector	06	16
Regional Arterial	03	13	Secondary Collector	07	17
Metro. Arterial		14	Residential	08	18
Local Arterial	05	15	Local Access	09	19
			Industrial - Comm.	10	20

8. Legal System 1-State Trunkline 2-County Primary 3-County Local 4-City Major 5-City Local
9. All Season Truck Route 1-Yes 2-No
10. BR, BL, BS Identification 1-BR 2-BL 3-BS
11. Federal Aid 1-Interstate 2-FAP 3-FAS 4-Non Federal Aid
12. Seasonal Road 1-No 2-Yes
13. Existing Functional Class.
14. Future Functional Class.

Number Of Structure and Grade Crossing Work Sheets Attached ________

COMMENTS

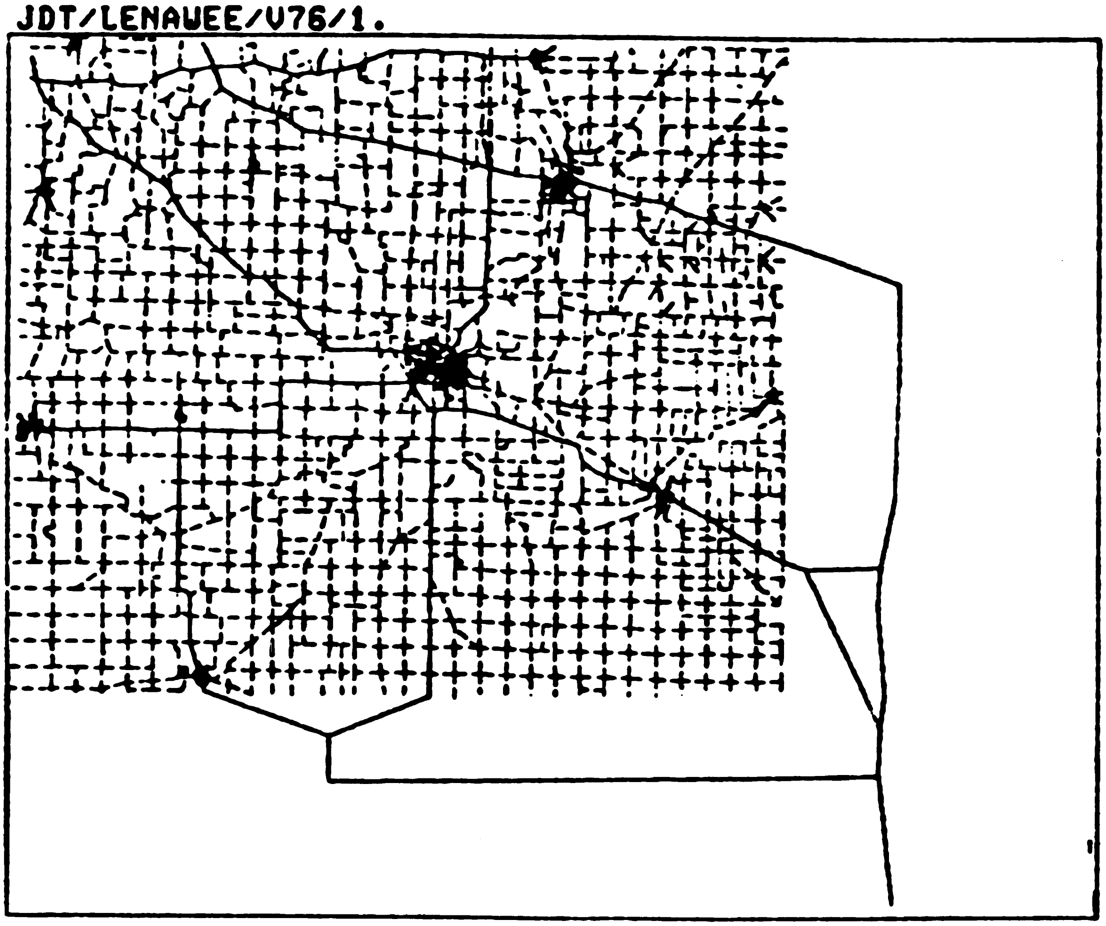
EXISTING CONDITIONS

15. Section Length (Hundredths of Mile)
16. Surface Type
17. Surface Width (Feet)
18. Surface Deterioration Factor 1-Excellent 2-Good 3-Fair 4-Poor 5-Very Poor
19. Year of Surface Improvement
20. Number of Traffic Lanes
21. Type Parking 0-None 1-Parallel One Side 2-Parallel Opp. Parallel 3-Angle One Side 4-Angle Opp. Parallel 5-Angle Opp. Angle
22. Outside Shoulder Width (Feet)
23. Inside Shoulder Width (Feet)
24. Shoulder Type 1-Paved 2-Stabilized 3-Earth
25. Curb and/or Gutter 0-None 1-One Side 2-Both Sides
26. Shoulder - Curb Condition 1-Good 2-Fair 3-Poor
27. Median Width (Feet)
28. Right-Of-Way (Feet)
29. Base Factor 1-Excellent 2-Good 3-Fair 4-Poor 5-Very Poor
30. Drainage Factor 1-Adequate 3-Tolerable 5-Inadequate
31. Traffic Operation 1-Freeway (Full Access Control) 2-Divided 3-One-way 4-Frwy.(Detroit Metro) 8-One-way Trunk (State Use) 9-Two Way Undivided
32. Direction of Travel On Divided 1-NB 2-SB 3-EB 4-WB
33. Terrain 0-All Urban 1-Level Rural 2-Rolling Rural
34. Average Daily Traffic (Tens) E-Est. A-Act.
35. 30th High Hour
36. Traffic Expansion Factor
37. Per Cent Commercial Vehicles
38. Per Cent Sight Restriction
39. Existing Land Use 1-Rural 2-Int. 3-CBD
40. Future Land Use 1-Rural 2-Int. 3-CBD
41. Mileage Control 1-No Change 2,3,4,5,6 - See Manual
42. Special Costing Code

APPENDIX B

INTEGRATED COMPUTER MAP OF LENAWEE COUNTY

Integrated Computer Map of Lenawee County

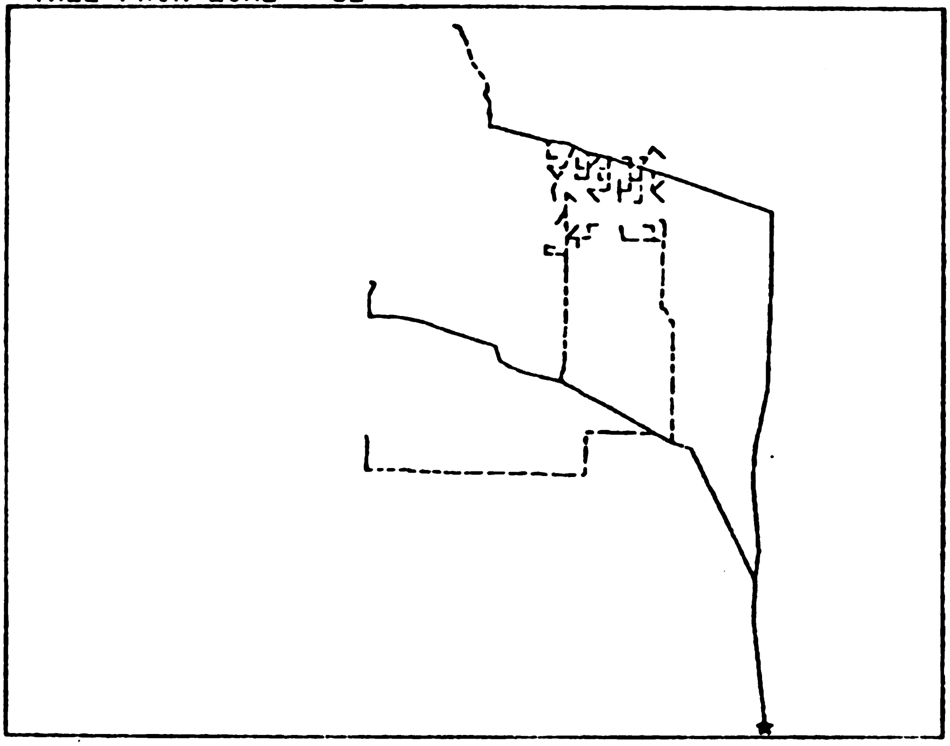


APPENDIX C

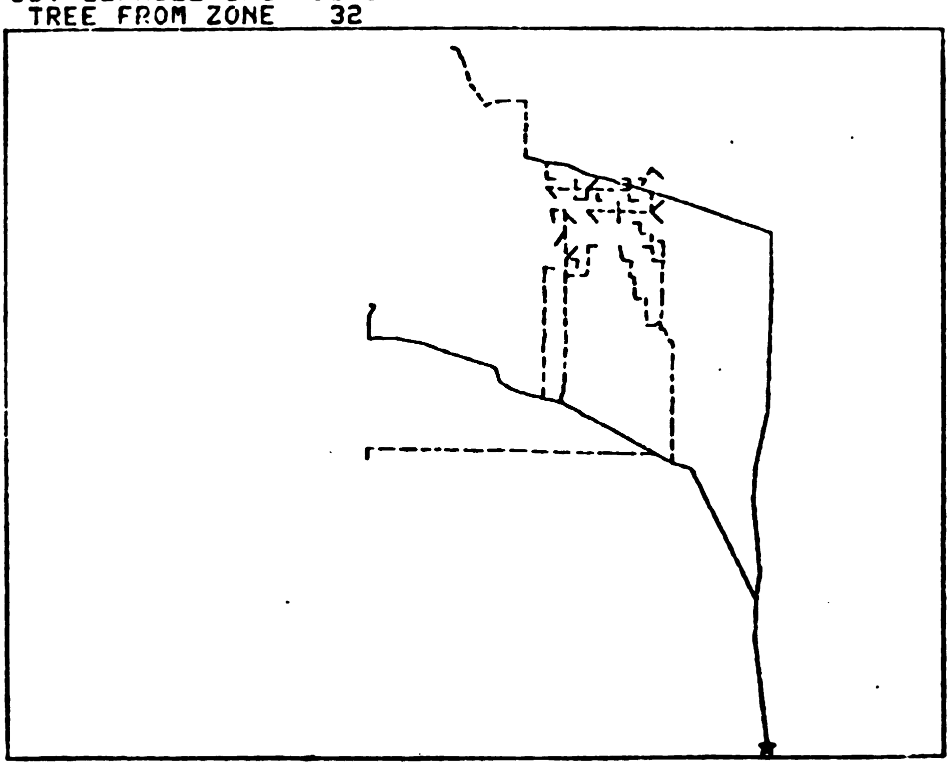
CHANGING ROUTE PATTERNS AS A RESULT OF CHANGING ROAD SURFACE TYPES

Computerized Base/Upgrade Map

JDT/LENAWEE/BASE/1.
TREE FROM ZONE 32



JDT/LENAWEE/UPGRADE/1.
TREE FROM ZONE 32



APPENDIX D

AVERAGE SPEED OF TRAVEL BY ROAD SURFACE TYPE

Road Surface Type	Average Safety Operating Speed (mph)
Unimproved Earth	10
Graded and Drained Earth	10
Gravel and Similar	20
Bituminous Surface Treated Gravel	30
Mixed Bituminous Surface on Gravel	35
Mixed Bituminous Surface on Concrete, Brick or Black Base	35
Concrete	40

APPENDIX E

ANNUAL MAINTENANCE COST PER MILE BY SURFACE TYPE, NUMBER OF LANES AND FUNCTIONAL CLASS

ANNUAL MAINTENANCE COSTS PER MILE BY

SURFACE TYPE AND NUMBER OF LANES

As Used in the

1974 Highway Needs Study Update

Transportation Planning Division

Michigan Department of State
Highways and Transportation

SURFACE TYPE EQUIVALENTS

Needs Study Code	Surface Type	Surface Type Code
6	Bituminous on Rigid Base	1
7	Concrete	
8	Brick	
5	Freeway Bituminous	
4	Bituminous on Flexible Base	2
9	Other	
3	Bituminous Surface Treated Gravel	3
2	Gravel and Similar	4
1	Graded and Drained Earth	
0	Unimproved Earth	

Per Program Listing

Functional Class	Surface Type	Number of Lanes	Annual Cost Per Mile
02 - Statewide Arterial (Rural)	1	2	$6,075
	1	4	8,100
	1	6	9,450
	2	2	5,400
03 - Regional Arterial (Rural)	1	2	4,725
	1	4	6,075
	1	6	7,425
	2	2	4,050
	2	4	5,400
	3	2	3,375
	4	2	1,080
05 - Local Arterial (Rural)	1	2	4,050
	1	4	5,400
	2	2	3,375
	2	4	4,725
	3	2	1,755
	4	2	945
06 - Principle Collector (Rural)	1	2	2,970
& 07 - Secondary Collector (Rural)	1	4	4,185
	2	2	1,755
	2	4	2,970
	3	2	1,350
	3	4	1,755
	4	2	945
08 - Residential (Rural)	1	2	2,295
& 18 - Residential (Urban)	1	4	3,240
	2	2	2,160
(F.C. 08) →	2	4	2,970
(F.C. 18) →	2	4	2,700
	3	2	1,620
	3	4	2,295
	4	2	1,350
	4	4	2,700
09 - Local Access (Rural)	1	2	1,620
	2	2	1,215
	3	2	945
	4	2	945
	4	4	1,890
10 - Industrial/Commercial (Rural)	1	2	4,725
& 20 - Industrial/Commercial (Urban)	1	4	7,425
	2	2	4,050
	2	4	6,750
	3	2	2,700
	4	2	2,430

Functional Class	Surface Type	Number of Lanes	Annual Cost Per Mile
12 - Statewide Arterial (Urban)	1	2	$ 8,100
	1	4	10,800
	1	6	14,175
	1	8	17,550
	2	2	7,425
	2	4	10,125
	2	6	13,500
13 - Regional Arterial (Urban)	1	2	7,425
	1	4	10,125
	1	6	13,500
	1	8	16,875
	2	2	6,750
	2	4	9,450
	2	6	13,500
	2	8	16,875
	3	2	3,375
	4	2	1,080
14 - Metro-Area Arterial (Urban)	1	2	6,750
	1	4	9,450
	1	6	12,825
	1	8	14,850
	2	2	6,075
	2	4	8,775
	2	6	10,800
	2	8	12,825
	3	2	4,725
	4	2	1,080
15 - Local Arterial (Urban)	1	2	6,750
	1	4	9,450
	1	6	11,475
	1	8	13,500
	2	2	5,400
	2	4	8,100
	2	6	10,125
	3	2	3,375
	4	2	945
16 - Principal Collector (Urban) &	1	2	5,400
17 - Secondary Collector (Urban)	1	4	8,100
	1	6	10,125
	2	2	4,050
	2	4	6,750
	2	6	8,775
	2	8	11,475
	3	2	2,700
	3	4	4,725
	4	2	945
	4	4	1,890

Functional Class	Surface Type	Number of Lanes	Annual Cost Per Mile
18 - (See 08)			
19 - Local Access (Urban)	1	2	$2,025
	2	2	1,350
	2	4	2,295
	3	2	1,350
	4	2	945
20 - (See 10)			

APPENDIX F

CONSTRUCTION COST PER MILE BY SURFACE TYPE FOR CONSTRUCTING A BITUMINOUS SURFACE ROAD

RURAL ROAD IMPROVEMENT COSTS BY ROAD TYPE*

Road Type	Upgrade to Bituminous Surface Cost Per Mile
Bituminous Surface Treated Gravel	$82,400
Gravel and Similar	$82,400
Graded and Drained Earth	$82,400
Unimproved Earth	$111,500

*Source: Michigan Department of State Highways and Transportation.

APPENDIX G

INTERSTATE COMMERCE COMMISSION TABLE II--LINE-HAUL COSTS ADJUSTED FOR EFFECT OF SPEED

TABLE II. LINE-HAUL COSTS ADJUSTED FOR EFFECT OF SPEED[1]

South Central Territory

Line No.	Line-Haul Running Speed (Miles Per-Hour) (1)	Total Line-Haul-Cost Per Vehicle-Mile (2)
1	42.9 Miles Per Hour (Actual Cost Study Average Speed)	52.230 ¢
2	15 Miles Per Hour (Assumed Speed).	108.725
3	20 Miles Per Hour (Assumed Speed).	87.008
4	25 Miles Per Hour (Assumed Speed).	73.978
5	30 Miles Per Hour (Assumed Speed).	65.291
6	35 Miles Per Hour (Assumed Speed).	59.086
7	40 Miles Per Hour (Assumed Speed).	54.432
8	45 Miles Per Hour (Assumed Speed).	50.813

[1]When the average speed for a specific haul is known to be substantially different from the overall speed for the cost study as shown on Line 1, Column 1 above, select from Column 2, above, or interpolate therefrom, the cost per vehicle-mile which corresponds with the known speed and substitute such cost for the overall cost shown on Line 1, Column 2.

See Item 10-B of explanatory data for description of the application of the data in this table to specific movements of traffic.

APPENDIX H

COMPUTER PRINTOUT--EXISTING RURAL ROAD INFRASTRUCTURE

OPTIMAL LINEAR PROGRAMMING SOLUTION

148	-16.3[illegible]
149	-[illegible].9[illegible]
150	-[illegible].7000
151	-16.8[illegible]
152	-[illegible]
153	-[illegible].6[illegible]
154	-17.3[illegible]
155	-27.[illegible]
156	-2[illegible].[illegible]00

START L. P. SOLVE

OPTIMAL SOLUTION (20)

OBJECTIVE FUNCTION=   -34095570.0000

ACTIVITIES IN SOLUTION

ACTIVITY	1	IS	80700.0000
ACTIVITY	7	IS	80700.0000
ACTIVITY	13	IS	80700.0000
ACTIVITY	19	IS	80700.0000
ACTIVITY	25	IS	80700.0000
ACTIVITY	31	IS	80700.0000
ACTIVITY	37	IS	80700.0000
ACTIVITY	46	IS	80700.0000
ACTIVITY	49	IS	80700.0000
ACTIVITY	55	IS	80700.0000
ACTIVITY	61	IS	80700.0000
ACTIVITY	67	IS	80700.0000
ACTIVITY	73	IS	80700.0000
ACTIVITY	79	IS	80700.0000
ACTIVITY	85	IS	80700.0000
ACTIVITY	91	IS	20700.0000
ACTIVITY	94	IS	6[illegible]500.0000
ACTIVITY	100	IS	80700.0000
ACTIVITY	106	IS	80700.0000
ACTIVITY	112	IS	80700.0000
ACTIVITY	118	IS	80700.0000
ACTIVITY	124	IS	80700.0000
ACTIVITY	130	IS	80700.0000
ACTIVITY	136	IS	80700.0000
ACTIVITY	142	IS	80700.0000
ACTIVITY	148	IS	80700.0000
ACTIVITY	154	IS	80700.0000

SHADOW PRICES AND SLACKS

ROW	1	PRICE	-20.3000	EXCESS	0.0000
ROW	2	PRICE	-2[illegible].4[illegible]	EXCESS	0.0000
ROW	3	PRICE	-19.4000	EXCESS	0.0000
ROW	4	PRICE	-20.1000	EXCESS	0.0000
ROW	5	PRICE	-2[illegible]	EXCESS	0.0000
ROW	6	PRICE	-21.[illegible]	EXCESS	0.0000
ROW	7	PRICE	-21.[illegible]	EXCESS	0.0000
ROW	8	PRICE	-21.1000	EXCESS	0.0000
ROW	9	PRICE	-2[illegible].1000	EXCESS	0.0000
ROW	10	PRICE	-2[illegible].4000	EXCESS	0.0000
ROW	11	PRICE	-[illegible].1000	EXCESS	0.0000
ROW	12	PRICE	-21.5000	EXCESS	0.0000
ROW	13	PRICE	-21.[illegible]	EXCESS	0.0000
ROW	14	PRICE	-21.[illegible]000	EXCESS	0.0000
ROW	15	PRICE	-2[illegible].4[illegible]	EXCESS	0.0000
ROW	16	PRICE	-21.1000	EXCESS	0.0000
ROW	17	PRICE	-1[illegible]	EXCESS	0.0000
ROW	18	PRICE	-[illegible]	EXCESS	0.0000
ROW	19	PRICE	-1[illegible].2[illegible]	EXCESS	0.0000
ROW	20	PRICE	-1[illegible].[illegible]	EXCESS	0.0000
ROW	21	PRICE	-1[illegible]	EXCESS	0.0000
ROW	22	PRICE	-19.[illegible]	EXCESS	0.0000
ROW	23	PRICE	-22.[illegible]	EXCESS	0.0000
ROW	24	PRICE	-22.4[illegible]	EXCESS	0.0000
ROW	25	PRICE	-1[illegible].3[illegible]	EXCESS	0.0000
ROW	26	PRICE	-17.7000	EXCESS	0.0000
ROW	27	PRICE	7.2000	EXCESS	0.0000
ROW	28	PRICE	0.0000	EXCESS	250000.0000
ROW	29	PRICE	0.0000	EXCESS	525000.0000
ROW	30	PRICE	[illegible].0000	EXCESS	2051800.0000
ROW	31	PRICE	[illegible].0000	EXCESS	2750000.0000
ROW	32	PRICE	-1.5000	EXCESS	0.0000

COST OF FORCING IN NONOPTIMAL ACTIVITIES

ACTIVITY	2	IS	7.7000
ACTIVITY	3	IS	10.1000
ACTIVITY	4	IS	4.[illegible]00
ACTIVITY	5	IS	14.1000
ACTIVITY	6	IS	5.4000
ACTIVITY	8	IS	8.[illegible]00
ACTIVITY	9	IS	[illegible].[illegible]00
ACTIVITY	10	IS	4.5000
ACTIVITY	11	IS	13.5000
ACTIVITY	12	IS	5.1000
ACTIVITY	14	IS	7.6000
ACTIVITY	15	IS	[illegible].[illegible]000
ACTIVITY	16	IS	4.[illegible]000
ACTIVITY	17	IS	13.6000
ACTIVITY	18	IS	6.1000
ACTIVITY	20	IS	6.[illegible]000
ACTIVITY	21	IS	6.[illegible]000
ACTIVITY	22	IS	3.7000
ACTIVITY	23	IS	9.[illegible]000
ACTIVITY	24	IS	[illegible].0000
ACTIVITY	26	IS	4.7000
ACTIVITY	27	IS	4.6000
ACTIVITY	28	IS	2.0000
ACTIVITY	29	IS	[illegible].9000
ACTIVITY	30	IS	7.[illegible]000
ACTIVITY	32	IS	1.7000
ACTIVITY	33	IS	4.5000
ACTIVITY	34	IS	2.0000
ACTIVITY	35	IS	8.3000
ACTIVITY	36	IS	7.6000
ACTIVITY	38	IS	2.[illegible]000
ACTIVITY	39	IS	3.6000
ACTIVITY	40	IS	1.3000
ACTIVITY	41	IS	7.9000
ACTIVITY	42	IS	7.9000
ACTIVITY	43	IS	1.5000
ACTIVITY	44	IS	5.5000
ACTIVITY	45	IS	4.3000
ACTIVITY	47	IS	8.[illegible]000
ACTIVITY	48	IS	[illegible].9000
ACTIVITY	50	IS	7.3000
ACTIVITY	51	IS	6.[illegible]000
ACTIVITY	52	IS	2.[illegible]000
ACTIVITY	53	IS	10.6000
ACTIVITY	54	IS	8.[illegible]000
ACTIVITY	56	IS	7.0000
ACTIVITY	57	IS	7.6000
ACTIVITY	58	IS	1.6000
ACTIVITY	59	IS	11.[illegible]000
ACTIVITY	60	IS	6.0000
ACTIVITY	62	IS	6.0000
ACTIVITY	63	IS	9.4000
ACTIVITY	64	IS	3.[illegible]000
ACTIVITY	65	IS	13.[illegible]000
ACTIVITY	66	IS	[illegible].[illegible]000
ACTIVITY	68	IS	6.6000
ACTIVITY	69	IS	9.4000
ACTIVITY	70	IS	2.4000
ACTIVITY	71	IS	13.4000
ACTIVITY	72	IS	3.[illegible]000
ACTIVITY	74	IS	[illegible].[illegible]000
ACTIVITY	75	IS	9.4000
ACTIVITY	76	IS	2.4000
ACTIVITY	77	IS	13.4000
ACTIVITY	78	IS	3.[illegible]000
ACTIVITY	80	IS	6.7000
ACTIVITY	81	IS	7.[illegible]000
ACTIVITY	82	IS	.[illegible]000
ACTIVITY	83	IS	11.6000
ACTIVITY	84	IS	5.2000
ACTIVITY	86	IS	7.0000
ACTIVITY	87	IS	7.6000
ACTIVITY	88	IS	1.6000

ACTIVITY	89	IS	11.2000
ACTIVITY	90	IS	6.9000
ACTIVITY	92	IS	7.0000
ACTIVITY	93	IS	4.6000
ACTIVITY	95	IS	8.6000
ACTIVITY	96	IS	7.8000
ACTIVITY	97	IS	3.4000
ACTIVITY	98	IS	7.0000
ACTIVITY	99	IS	4.7000
ACTIVITY	101	IS	8.7000
ACTIVITY	102	IS	6.7000
ACTIVITY	103	IS	1.4000
ACTIVITY	104	IS	5.0000
ACTIVITY	105	IS	2.0000
ACTIVITY	107	IS	6.4000
ACTIVITY	108	IS	8.8000
ACTIVITY	109	IS	5.5000
ACTIVITY	110	IS	9.5000
ACTIVITY	111	IS	5.7000
ACTIVITY	113	IS	9.4000
ACTIVITY	114	IS	6.9000
ACTIVITY	115	IS	8.1000
ACTIVITY	116	IS	13.0000
ACTIVITY	117	IS	6.6000
ACTIVITY	119	IS	10.2000
ACTIVITY	120	IS	6.5000
ACTIVITY	121	IS	4.6000
ACTIVITY	122	IS	11.8000
ACTIVITY	123	IS	7.0000
ACTIVITY	125	IS	10.6000
ACTIVITY	126	IS	6.7000
ACTIVITY	127	IS	3.0000
ACTIVITY	128	IS	10.7000
ACTIVITY	129	IS	6.9000
ACTIVITY	131	IS	10.7000
ACTIVITY	132	IS	3.7000
ACTIVITY	133	IS	1.7000
ACTIVITY	134	IS	8.7000
ACTIVITY	135	IS	6.7000
ACTIVITY	137	IS	10.3000
ACTIVITY	138	IS	.4000
ACTIVITY	139	IS	1.6000
ACTIVITY	140	IS	8.7000
ACTIVITY	141	IS	7.4000
ACTIVITY	143	IS	11.0000
ACTIVITY	145	IS	10.0000
ACTIVITY	146	IS	13.3000
ACTIVITY	147	IS	6.9000
ACTIVITY	149	IS	10.6000
ACTIVITY	150	IS	7.9000
ACTIVITY	151	IS	6.7000
ACTIVITY	152	IS	12.7000
ACTIVITY	153	IS	6.6000
ACTIVITY	155	IS	10.2000
ACTIVITY	156	IS	6.5000

PRICE RANGE OVER WHICH OPTIMAL SOLUTION HOLDS

		ACTIVITY	PRICE	ACTIVITY	PRICE
		LOWER BOUND		UPPER BOUND	
ACTIVITY	1	4	-18.5000	157	7.2000
ACTIVITY	7	10	-17.7000	158	7.2000
ACTIVITY	13	16	-17.2000	159	7.2000
ACTIVITY	19	22	-16.6000	160	7.2000
ACTIVITY	25	28	-15.6000	161	7.2000
ACTIVITY	31	34	-14.8000	162	7.2000
ACTIVITY	37	40	-15.9000	163	7.2000
ACTIVITY	46	43	-22.4000	164	.0000
ACTIVITY	49	52	-15.2000	165	7.2000
ACTIVITY	55	58	-14.8000	166	7.2000
ACTIVITY	61	64	-15.9000	167	7.2000
ACTIVITY	67	70	-16.7000	168	7.2000
ACTIVITY	73	76	-16.7000	169	7.2000
ACTIVITY	79	82	-15.5000	170	7.2000
ACTIVITY	85	88	-14.8000	171	7.2000
ACTIVITY	91	133	-15.2000	82	-13.5000
ACTIVITY	94	82	-22.0000	133	-19.5000
ACTIVITY	100	97	-23.0000	173	.0000
ACTIVITY	106	103	-22.8000	174	.0000
ACTIVITY	112	109	-23.7000	175	.0000
ACTIVITY	118	119	-22.1000	176	.0000
ACTIVITY	124	121	-23.7000	177	.0000
ACTIVITY	130	127	-22.6000	178	.0000
ACTIVITY	136	138	-22.4000	179	0.0000
ACTIVITY	142	148	-23.9000	138	-22.0000
ACTIVITY	144	158	-24.3000	188	-22.4000
ACTIVITY	148	147	-23.2000	181	.0000
ACTIVITY	154	156	-23.8000	182	.0000

APPENDIX I

COMPUTER PRINTOUT--DEVELOPED RURAL ROAD INFRASTRUCTURE

OPTIMAL LINEAR PROGRAMMING SOLUTION

148	-14.8000
149	-24.2000
150	-24.0000
151	-14.0000
152	-26.2000
153	-23.2000
154	-15.6000
155	-26.0000
156	-24.6000

START L. P. SOLVE

OPTIMAL SOLUTION (30)

OBJECTIVE FUNCTION= -29713560.0000

ACTIVITIES IN SOLUTION

ACTIVITY	1	IS	80700.0000
ACTIVITY	7	IS	80700.0000
ACTIVITY	13	IS	80700.0000
ACTIVITY	19	IS	80700.0000
ACTIVITY	25	IS	80700.0000
ACTIVITY	31	IS	80700.0000
ACTIVITY	37	IS	80700.0000
ACTIVITY	43	IS	80700.0000
ACTIVITY	49	IS	80700.0000
ACTIVITY	55	IS	80700.0000
ACTIVITY	61	IS	80700.0000
ACTIVITY	67	IS	80700.0000
ACTIVITY	73	IS	80700.0000
ACTIVITY	79	IS	80700.0000
ACTIVITY	85	IS	80700.0000
ACTIVITY	91	IS	20200.0000
ACTIVITY	94	IS	60500.0000
ACTIVITY	100	IS	80700.0000
ACTIVITY	106	IS	80700.0000
ACTIVITY	112	IS	80700.0000
ACTIVITY	118	IS	80700.0000
ACTIVITY	124	IS	80700.0000
ACTIVITY	130	IS	80700.0000
ACTIVITY	136	IS	80700.0000
ACTIVITY	142	IS	80700.0000
ACTIVITY	148	IS	80700.0000
ACTIVITY	154	IS	80700.0000

SHADOW PRICES AND SLACKS

ROW	1	PRICE	-18.4000	EXCESS	0.0000
ROW	2	PRICE	-18.0000	EXCESS	0.0000
ROW	3	PRICE	-17.4000	EXCESS	0.0000
ROW	4	PRICE	-18.0000	EXCESS	0.0000
ROW	5	PRICE	-18.0000	EXCESS	0.0000
ROW	6	PRICE	-19.8000	EXCESS	0.0000
ROW	7	PRICE	-19.6000	EXCESS	0.0000
ROW	8	PRICE	-18.8000	EXCESS	0.0000
ROW	9	PRICE	-17.8000	EXCESS	0.0000
ROW	10	PRICE	-18.4000	EXCESS	0.0000
ROW	11	PRICE	-18.0000	EXCESS	0.0000
ROW	12	PRICE	-18.8000	EXCESS	0.0000
ROW	13	PRICE	-18.8000	EXCESS	0.0000
ROW	14	PRICE	-19.2000	EXCESS	0.0000
ROW	15	PRICE	-18.4000	EXCESS	0.0000
ROW	16	PRICE	-18.8000	EXCESS	0.0000
ROW	17	PRICE	-17.8000	EXCESS	0.0000
ROW	18	PRICE	-18.2000	EXCESS	0.0000
ROW	19	PRICE	-17.0000	EXCESS	0.0000
ROW	20	PRICE	-16.0000	EXCESS	0.0000
ROW	21	PRICE	-17.8000	EXCESS	0.0000
ROW	22	PRICE	-18.2000	EXCESS	0.0000
ROW	23	PRICE	-19.2000	EXCESS	0.0000
ROW	24	PRICE	-20.0000	EXCESS	0.0000
ROW	25	PRICE	-14.8000	EXCESS	0.0000
ROW	26	PRICE	-15.6000	EXCESS	0.0000
ROW	27	PRICE	7.2000	EXCESS	0.0000
ROW	28	PRICE	0.0000	EXCESS	250000.0000
ROW	29	PRICE	0.0000	EXCESS	525000.0000
ROW	30	PRICE	0.0000	EXCESS	2051800.0000
ROW	31	PRICE	0.0000	EXCESS	2750000.0000
ROW	32	PRICE	-3.0000	EXCESS	0.0000

COST OF FORCING IN NONOPTIMAL ACTIVITIES

ACTIVITY	2	IS	8.6000
ACTIVITY	3	IS	10.2000
ACTIVITY	4	IS	4.2000
ACTIVITY	5	IS	13.0000
ACTIVITY	6	IS	5.8000
ACTIVITY	8	IS	8.6000
ACTIVITY	9	IS	10.2000
ACTIVITY	10	IS	4.0000
ACTIVITY	11	IS	13.0000
ACTIVITY	12	IS	6.0000
ACTIVITY	14	IS	8.6000
ACTIVITY	15	IS	10.2000
ACTIVITY	16	IS	4.2000
ACTIVITY	17	IS	13.0000
ACTIVITY	18	IS	6.6000
ACTIVITY	20	IS	7.0000
ACTIVITY	21	IS	7.6000
ACTIVITY	22	IS	2.0000
ACTIVITY	23	IS	10.2000
ACTIVITY	24	IS	7.8000
ACTIVITY	26	IS	7.0000
ACTIVITY	27	IS	6.8000
ACTIVITY	28	IS	2.0000
ACTIVITY	29	IS	9.4000
ACTIVITY	30	IS	8.0000
ACTIVITY	32	IS	3.4000
ACTIVITY	33	IS	5.0000
ACTIVITY	34	IS	.8000
ACTIVITY	35	IS	8.4000
ACTIVITY	36	IS	7.8000
ACTIVITY	38	IS	3.8000
ACTIVITY	39	IS	5.2000
ACTIVITY	40	IS	.4000
ACTIVITY	41	IS	7.8000
ACTIVITY	42	IS	7.6000
ACTIVITY	44	IS	6.4000
ACTIVITY	45	IS	6.0000
ACTIVITY	47	IS	8.6000
ACTIVITY	48	IS	8.0000
ACTIVITY	50	IS	7.8000
ACTIVITY	51	IS	8.0000
ACTIVITY	52	IS	2.2000
ACTIVITY	53	IS	10.6000
ACTIVITY	54	IS	8.0000
ACTIVITY	56	IS	8.6000
ACTIVITY	57	IS	7.8000
ACTIVITY	58	IS	1.6000
ACTIVITY	59	IS	10.4000
ACTIVITY	60	IS	6.6000
ACTIVITY	62	IS	8.6000
ACTIVITY	63	IS	9.2000
ACTIVITY	64	IS	3.0000
ACTIVITY	65	IS	12.0000
ACTIVITY	66	IS	6.2000
ACTIVITY	68	IS	8.8000
ACTIVITY	69	IS	8.8000
ACTIVITY	70	IS	2.2000
ACTIVITY	71	IS	11.6000
ACTIVITY	72	IS	4.4000
ACTIVITY	74	IS	6.4000
ACTIVITY	75	IS	8.6000
ACTIVITY	76	IS	2.2000
ACTIVITY	77	IS	11.6000
ACTIVITY	78	IS	4.4000
ACTIVITY	80	IS	8.4000
ACTIVITY	81	IS	8.0000
ACTIVITY	82	IS	1.0000
ACTIVITY	83	IS	10.8000
ACTIVITY	84	IS	2.2000
ACTIVITY	86	IS	8.6000
ACTIVITY	87	IS	7.8000
ACTIVITY	88	IS	1.6000
ACTIVITY	89	IS	10.4000

ACTIVITY	90	IS	6.6000
ACTIVITY	92	IS	6.8000
ACTIVITY	93	IS	6.0000
ACTIVITY	95	IS	8.6000
ACTIVITY	96	IS	7.2000
ACTIVITY	97	IS	2.0000
ACTIVITY	98	IS	8.2000
ACTIVITY	99	IS	6.4000
ACTIVITY	101	IS	9.4000
ACTIVITY	102	IS	6.0000
ACTIVITY	103	IS	1.6000
ACTIVITY	104	IS	7.0000
ACTIVITY	105	IS	5.0000
ACTIVITY	107	IS	7.2000
ACTIVITY	108	IS	5.8000
ACTIVITY	109	IS	3.2000
ACTIVITY	110	IS	9.2000
ACTIVITY	111	IS	6.6000
ACTIVITY	113	IS	9.0000
ACTIVITY	114	IS	5.6000
ACTIVITY	115	IS	6.0000
ACTIVITY	116	IS	11.6000
ACTIVITY	117	IS	6.6000
ACTIVITY	119	IS	9.2000
ACTIVITY	120	IS	5.2000
ACTIVITY	121	IS	2.4000
ACTIVITY	122	IS	9.2000
ACTIVITY	123	IS	6.4000
ACTIVITY	125	IS	9.4000
ACTIVITY	126	IS	5.0000
ACTIVITY	127	IS	2.0000
ACTIVITY	128	IS	10.8000
ACTIVITY	129	IS	7.4000
ACTIVITY	131	IS	10.0000
ACTIVITY	132	IS	2.6000
ACTIVITY	133	IS	1.0000
ACTIVITY	134	IS	9.8000
ACTIVITY	135	IS	8.0000
ACTIVITY	137	IS	10.2000
ACTIVITY	138	IS	.8000
ACTIVITY	139	IS	.6000
ACTIVITY	140	IS	9.6000
ACTIVITY	141	IS	8.0000
ACTIVITY	143	IS	9.8000
ACTIVITY	145	IS	8.4000
ACTIVITY	146	IS	12.2000
ACTIVITY	147	IS	7.0000
ACTIVITY	149	IS	9.4000
ACTIVITY	150	IS	6.2000
ACTIVITY	151	IS	5.6000
ACTIVITY	152	IS	12.6000
ACTIVITY	153	IS	7.6000
ACTIVITY	155	IS	10.4000
ACTIVITY	156	IS	6.0000

PRICE RANGE OVER WHICH OPTIMAL SOLUTION HOLDS

		ACTIVITY LOWER BOUND	PRICE	ACTIVITY UPPER BOUND	PRICE
ACTIVITY	1	4	-15.4000	157	7.2000
ACTIVITY	7	10	-14.8000	158	7.2000
ACTIVITY	13	16	-14.4000	159	7.2000
ACTIVITY	19	22	-12.8000	160	7.2000
ACTIVITY	25	28	-12.2000	161	7.2000
ACTIVITY	31	34	-13.4000	162	7.2000
ACTIVITY	37	40	-12.6000	163	7.2000
ACTIVITY	43	****	-I	****	-I
ACTIVITY	46	45	-26.8000	164	.0000
ACTIVITY	49	52	-12.8000	165	7.2000
ACTIVITY	55	58	-12.8000	166	7.2000
ACTIVITY	61	64	-13.8000	167	7.2000
ACTIVITY	67	70	-13.8000	168	7.2000
ACTIVITY	73	76	-13.6000	169	7.2000
ACTIVITY	79	82	-13.0000	170	7.2000
ACTIVITY	85	88	-12.9000	171	7.2000
ACTIVITY	91	139	-12.2000	40	-11.2000
ACTIVITY	94	40	-19.2000	139	-18.2000

ACTIVITY	100	97	-19.8000	173	.0000
ACTIVITY	106	103	-19.6000	174	.0000
ACTIVITY	112	109	-20.2000	175	0.0000
ACTIVITY	118	120	-21.2000	176	0.0000
ACTIVITY	124	121	-20.2000	177	.0000
ACTIVITY	130	127	-20.2000	178	.0000
ACTIVITY	136	138	-20.0000	179	.0000
ACTIVITY	142	139	-20.0000	138	-19.2000
ACTIVITY	144	138	-23.8000	180	-20.0000
ACTIVITY	148	150	-21.0000	181	.0000
ACTIVITY	154	151	-21.2000	182	.0000

APPENDIX J

COMPUTER PRINTOUT--5 YEAR DETERIORATION OF THE RURAL ROAD INFRASTRUCTURE OPTIMAL LINEAR PROGRAMMING SOLUTION

148	-18.2000
149	-26.9000
150	-26.2000
151	-16.8000
152	-32.9000
153	-23.9000
154	-17.8000
155	-27.5000
156	-25.3000

START L. P. SOLVE

OPTIMAL SOLUTION (29)

OBJECTIVE FUNCTION= -34936840.0000

ACTIVITIES IN SOLUTION

ACTIVITY	1	IS	80700.0000
ACTIVITY	7	IS	80700.0000
ACTIVITY	13	IS	80700.0000
ACTIVITY	19	IS	80700.0000
ACTIVITY	25	IS	80700.0000
ACTIVITY	31	IS	80700.0000
ACTIVITY	37	IS	80700.0000
ACTIVITY	43	IS	20200.0000
ACTIVITY	46	IS	60500.0000
ACTIVITY	49	IS	80700.0000
ACTIVITY	55	IS	80700.0000
ACTIVITY	61	IS	80700.0000
ACTIVITY	67	IS	80700.0000
ACTIVITY	73	IS	80700.0000
ACTIVITY	82	IS	80700.0000
ACTIVITY	85	IS	80700.0000
ACTIVITY	91	IS	80700.0000
ACTIVITY	100	IS	80700.0000
ACTIVITY	106	IS	80700.0000
ACTIVITY	112	IS	80700.0000
ACTIVITY	118	IS	80700.0000
ACTIVITY	124	IS	80700.0000
ACTIVITY	130	IS	80700.0000
ACTIVITY	136	IS	80700.0000
ACTIVITY	142	IS	80700.0000
ACTIVITY	148	IS	80700.0000
ACTIVITY	154	IS	80700.0000

SHADOW PRICES AND SLACKS

ROW	1	PRICE	-23.9000	EXCESS	0.0000
ROW	2	PRICE	-21.9000	EXCESS	0.0000
ROW	3	PRICE	-20.8000	EXCESS	0.0000
ROW	4	PRICE	-21.2000	EXCESS	0.0000
ROW	5	PRICE	-21.9000	EXCESS	0.0000
ROW	6	PRICE	-22.9000	EXCESS	0.0000
ROW	7	PRICE	-22.9000	EXCESS	0.0000
ROW	8	PRICE	-23.5000	EXCESS	0.0000
ROW	9	PRICE	-21.2000	EXCESS	0.0000
ROW	10	PRICE	-21.5000	EXCESS	0.0000
ROW	11	PRICE	-21.9000	EXCESS	0.0000
ROW	12	PRICE	-23.4000	EXCESS	0.0000
ROW	13	PRICE	-23.4000	EXCESS	0.0000
ROW	14	PRICE	-23.1000	EXCESS	0.0000
ROW	15	PRICE	-21.5000	EXCESS	0.0000
ROW	16	PRICE	-22.2000	EXCESS	0.0000
ROW	17	PRICE	-20.2000	EXCESS	0.0000
ROW	18	PRICE	-20.0000	EXCESS	0.0000
ROW	19	PRICE	-18.2000	EXCESS	0.0000
ROW	20	PRICE	-16.6000	EXCESS	0.0000
ROW	21	PRICE	-19.1000	EXCESS	0.0000
ROW	22	PRICE	-19.6000	EXCESS	0.0000
ROW	23	PRICE	-22.4000	EXCESS	0.0000
ROW	24	PRICE	-22.4000	EXCESS	0.0000
ROW	25	PRICE	-18.2000	EXCESS	0.0000
ROW	26	PRICE	-17.3000	EXCESS	0.0000
ROW	27	PRICE	8.3000	EXCESS	0.0000
ROW	28	PRICE	0.0000	EXCESS	250000.0000
ROW	29	PRICE	0.0000	EXCESS	525000.0000
ROW	30	PRICE	0.0000	EXCESS	2251800.0000
ROW	31	PRICE	0.0000	EXCESS	2750000.0000
ROW	32	PRICE	-1.5000	EXCESS	0.0000

COST OF FORCING IN NONOPTIMAL ACTIVITIES

ACTIVITY	2	IS	6.3000
ACTIVITY	3	IS	8.7000
ACTIVITY	4	IS	3.6000
ACTIVITY	5	IS	12.0000
ACTIVITY	6	IS	4.0000
ACTIVITY	8	IS	4.8000
ACTIVITY	9	IS	8.6000
ACTIVITY	10	IS	3.3000
ACTIVITY	11	IS	12.4000
ACTIVITY	12	IS	4.3000
ACTIVITY	14	IS	6.2000
ACTIVITY	15	IS	8.7000
ACTIVITY	16	IS	3.8000
ACTIVITY	17	IS	12.6000
ACTIVITY	18	IS	4.9000
ACTIVITY	20	IS	4.0000
ACTIVITY	21	IS	4.5000
ACTIVITY	22	IS	2.6000
ACTIVITY	23	IS	6.5000
ACTIVITY	24	IS	6.9000
ACTIVITY	26	IS	3.6000
ACTIVITY	27	IS	3.5000
ACTIVITY	28	IS	.9000
ACTIVITY	29	IS	7.8000
ACTIVITY	30	IS	6.5000
ACTIVITY	32	IS	.6000
ACTIVITY	33	IS	3.4000
ACTIVITY	34	IS	.9000
ACTIVITY	35	IS	7.2000
ACTIVITY	36	IS	6.5000
ACTIVITY	38	IS	1.7000
ACTIVITY	39	IS	2.5000
ACTIVITY	40	IS	.2000
ACTIVITY	41	IS	6.8000
ACTIVITY	42	IS	6.8000
ACTIVITY	44	IS	3.8000
ACTIVITY	45	IS	2.6000
ACTIVITY	47	IS	6.6000
ACTIVITY	48	IS	6.3000
ACTIVITY	50	IS	6.2000
ACTIVITY	51	IS	5.7000
ACTIVITY	52	IS	1.2000
ACTIVITY	53	IS	9.5000
ACTIVITY	54	IS	6.4000
ACTIVITY	56	IS	5.0000
ACTIVITY	57	IS	6.5000
ACTIVITY	58	IS	.5000
ACTIVITY	59	IS	10.1000
ACTIVITY	60	IS	6.6000
ACTIVITY	62	IS	5.8000
ACTIVITY	63	IS	8.4000
ACTIVITY	64	IS	2.9000
ACTIVITY	65	IS	12.4000
ACTIVITY	66	IS	4.5000
ACTIVITY	68	IS	5.9000
ACTIVITY	69	IS	6.2000
ACTIVITY	70	IS	.5000
ACTIVITY	71	IS	10.4000
ACTIVITY	72	IS	2.6000
ACTIVITY	74	IS	5.5000
ACTIVITY	75	IS	6.2000
ACTIVITY	76	IS	.3000
ACTIVITY	77	IS	10.4000
ACTIVITY	78	IS	2.6000
ACTIVITY	79	IS	.9000
ACTIVITY	80	IS	7.3000
ACTIVITY	81	IS	7.0000
ACTIVITY	83	IS	11.2000
ACTIVITY	84	IS	4.5000
ACTIVITY	86	IS	5.4000
ACTIVITY	87	IS	6.5000
ACTIVITY	88	IS	.5000
ACTIVITY	89	IS	10.1000

ACTIVITY	90	IS	6.6000
ACTIVITY	92	IS	5.9000
ACTIVITY	93	IS	3.5000
ACTIVITY	94	IS	.2000
ACTIVITY	95	IS	7.1000
ACTIVITY	96	IS	6.7000
ACTIVITY	97	IS	3.5000
ACTIVITY	98	IS	7.2000
ACTIVITY	99	IS	4.4000
ACTIVITY	101	IS	8.5000
ACTIVITY	102	IS	6.6000
ACTIVITY	103	IS	2.8000
ACTIVITY	104	IS	5.[illegible]
ACTIVITY	105	IS	2.6000
ACTIVITY	107	IS	6.4000
ACTIVITY	108	IS	8.8000
ACTIVITY	109	IS	6.6000
ACTIVITY	110	IS	11.1000
ACTIVITY	111	IS	6.1000
ACTIVITY	113	IS	9.8000
ACTIVITY	114	IS	6.9000
ACTIVITY	115	IS	9.2000
ACTIVITY	116	IS	13.3000
ACTIVITY	117	IS	6.6000
ACTIVITY	119	IS	10.3000
ACTIVITY	120	IS	6.5000
ACTIVITY	121	IS	5.7000
ACTIVITY	122	IS	11.8000
ACTIVITY	123	IS	7.2000
ACTIVITY	125	IS	10.6000
ACTIVITY	126	IS	6.3000
ACTIVITY	127	IS	4.1000
ACTIVITY	128	IS	10.3000
ACTIVITY	129	IS	4.9000
ACTIVITY	131	IS	10.7000
ACTIVITY	132	IS	3.7000
ACTIVITY	133	IS	3.7000
ACTIVITY	134	IS	9.7000
ACTIVITY	135	IS	7.2000
ACTIVITY	137	IS	10.9000
ACTIVITY	138	IS	.7000
ACTIVITY	139	IS	3.5000
ACTIVITY	140	IS	5.9000
ACTIVITY	141	IS	7.4000
ACTIVITY	143	IS	11.3000
ACTIVITY	145	IS	9.2000
ACTIVITY	146	IS	11.4000
ACTIVITY	147	IS	5.9000
ACTIVITY	149	IS	8.7000
ACTIVITY	150	IS	6.5000
ACTIVITY	151	IS	7.8000
ACTIVITY	152	IS	12.7000
ACTIVITY	153	IS	6.6000
ACTIVITY	155	IS	10.2000
ACTIVITY	156	IS	6.5000

ACTIVITY	100	97	-24.1000	173	.0000
ACTIVITY	106	103	-27.4000	174	.0000
ACTIVITY	112	111	-24.3000	175	.0000
ACTIVITY	118	120	-23.1000	176	.0000
ACTIVITY	124	121	-24.6000	177	.0000
ACTIVITY	130	132	-23.7000	178	.0000
ACTIVITY	136	134	-23.1000	179	.0000
ACTIVITY	142	188	-23.9000	138	-21.7000
ACTIVITY	144	138	-24.6000	168	-22.4000
ACTIVITY	148	147	-23.2000	181	.0000
ACTIVITY	154	156	-23.8000	182	.0000

PRICE RANGE OVER WHICH OPTIMAL SOLUTION HOLDS

		ACTIVITY LOWER BOUND	PRICE	ACTIVITY UPPER BOUND	PRICE
ACTIVITY	1	4	-18.3000	157	8.3000
ACTIVITY	7	10	-16.9000	158	8.3000
ACTIVITY	13	16	-16.3000	159	8.3000
ACTIVITY	19	22	-15.5000	160	8.3000
ACTIVITY	25	28	-14.5000	161	8.3000
ACTIVITY	31	32	-15.2000	162	8.3000
ACTIVITY	37	40	-14.8000	163	8.4000
ACTIVITY	43	79	-16.1000	41	-15.[illegible]
ACTIVITY	46	40	-23.7000	79	-22.6000
ACTIVITY	49	52	-14.1000	165	8.3000
ACTIVITY	55	58	-13.7000	166	8.3000
ACTIVITY	61	64	-15.6000	167	8.3000
ACTIVITY	67	70	-15.6000	168	8.3000
ACTIVITY	73	76	-15.6000	169	8.3000
ACTIVITY	82	79	-29.3000	170	.0000
ACTIVITY	85	88	-13.7000	171	8.3000
ACTIVITY	91	94	-14.1000	172	8.3000
ACTIVITY					

APPENDIX K

COMPUTER PRINTOUT--10 YEAR DETERIORATION OF THE RURAL ROAD INFRASTRUCTURE OPTIMAL LINEAR PROGRAMMING SOLUTION

149	-27.9000
150	-26.6000
151	-16.8000
152	-20.0000
153	-21.2000
154	-17.3000
155	-16.5000
156	-25.3000

START L. P. SOLVE

OPTIMAL SOLUTION (31)

OBJECTIVE FUNCTION= -3603320.0000

ACTIVITIES IN SOLUTION

ACTIVITY	1	IS	80700.0000
ACTIVITY	7	IS	80700.0000
ACTIVITY	13	IS	80700.0000
ACTIVITY	19	IS	80700.0000
ACTIVITY	25	IS	80700.0000
ACTIVITY	31	IS	80700.0000
ACTIVITY	37	IS	80700.0000
ACTIVITY	46	IS	80700.0000
ACTIVITY	49	IS	80700.0000
ACTIVITY	55	IS	[illegible]
ACTIVITY	58	IS	60900.0000
ACTIVITY	61	IS	80700.0000
ACTIVITY	67	IS	80700.0000
ACTIVITY	73	IS	80700.0000
ACTIVITY	79	IS	80700.0000
ACTIVITY	85	IS	80700.0000
ACTIVITY	91	IS	80700.0000
ACTIVITY	100	IS	80700.0000
ACTIVITY	106	IS	80700.0000
ACTIVITY	112	IS	80700.0000
ACTIVITY	118	IS	80700.0000
ACTIVITY	124	IS	80700.0000
ACTIVITY	130	IS	80700.0000
ACTIVITY	136	IS	80700.0000
ACTIVITY	142	IS	80700.0000
ACTIVITY	148	IS	80700.0000
ACTIVITY	154	IS	80700.0000

SHADOW PRICES AND SLACKS

ROW	1	PRICE	-23.2000	EXCESS	0.0000
ROW	2	PRICE	-22.1200	EXCESS	0.0000
ROW	3	PRICE	-21.0000	EXCESS	0.0000
ROW	4	PRICE	-22.1000	EXCESS	0.0000
ROW	5	PRICE	-23.6000	EXCESS	0.0000
ROW	6	PRICE	-24.3000	EXCESS	0.0000
ROW	7	PRICE	-27.9000	EXCESS	0.0000
ROW	8	PRICE	-23.3000	EXCESS	0.0000
ROW	9	PRICE	-22.3000	EXCESS	0.0000
ROW	10	PRICE	-22.4000	EXCESS	0.0000
ROW	11	PRICE	-22.1000	EXCESS	0.0000
ROW	12	PRICE	-22.6000	EXCESS	0.0000
ROW	13	PRICE	-23.6000	EXCESS	0.0000
ROW	14	PRICE	-24.4000	EXCESS	0.0000
ROW	15	PRICE	-22.4000	EXCESS	0.0000
ROW	16	PRICE	-22.2000	EXCESS	0.0000
ROW	17	PRICE	-21.9000	EXCESS	0.0000
ROW	18	PRICE	-20.0000	EXCESS	0.0000
ROW	19	PRICE	-19.6000	EXCESS	0.0000
ROW	20	PRICE	-16.6000	EXCESS	0.0000
ROW	21	PRICE	-19.1000	EXCESS	0.0000
ROW	22	PRICE	-19.6000	EXCESS	0.0000
ROW	23	PRICE	-22.7000	EXCESS	0.0000
ROW	24	PRICE	-22.7000	EXCESS	0.0000
ROW	25	PRICE	-16.5000	EXCESS	0.0000
ROW	26	PRICE	-17.5000	EXCESS	0.0000
ROW	27	PRICE	6.5000	EXCESS	0.0000
ROW	28	PRICE	0.0000	EXCESS	250000.0000
ROW	29	PRICE	0.0000	EXCESS	525000.0000
ROW	30	PRICE	0.0000	EXCESS	2051800.0000
ROW	31	PRICE	0.0000	EXCESS	2750000.0000
ROW	32	PRICE	-1.5000	EXCESS	0.0000

COST OF FORCING IN NONOPTIMAL ACTIVITIES

ACTIVITY	2	IS	6.1000
ACTIVITY	3	IS	8.1000
ACTIVITY	4	IS	3.4000
ACTIVITY	5	IS	12.7000
ACTIVITY	6	IS	3.8000
ACTIVITY	8	IS	5.6000
ACTIVITY	9	IS	8.4000
ACTIVITY	10	IS	3.6000
ACTIVITY	11	IS	12.2000
ACTIVITY	12	IS	4.1000
ACTIVITY	14	IS	6.3000
ACTIVITY	15	IS	8.5000
ACTIVITY	16	IS	3.6000
ACTIVITY	17	IS	12.4000
ACTIVITY	18	IS	4.7000
ACTIVITY	20	IS	4.0000
ACTIVITY	21	IS	[illegible]
ACTIVITY	22	IS	2.6000
ACTIVITY	23	IS	9.0000
ACTIVITY	24	IS	6.3000
ACTIVITY	26	IS	2.6000
ACTIVITY	27	IS	2.3000
ACTIVITY	28	IS	.7000
ACTIVITY	29	IS	6.1000
ACTIVITY	30	IS	6.4000
ACTIVITY	32	IS	.5000
ACTIVITY	33	IS	2.8000
ACTIVITY	34	IS	.8000
ACTIVITY	35	IS	6.6000
ACTIVITY	36	IS	5.7000
ACTIVITY	38	IS	1.7000
ACTIVITY	39	IS	2.5000
ACTIVITY	40	IS	.9000
ACTIVITY	41	IS	6.6000
ACTIVITY	42	IS	6.4000
ACTIVITY	43	IS	.7000
ACTIVITY	44	IS	3.4000
ACTIVITY	45	IS	2.2000
ACTIVITY	47	IS	6.2000
ACTIVITY	48	IS	6.7000
ACTIVITY	50	IS	5.6000
ACTIVITY	51	IS	8.4000
ACTIVITY	52	IS	1.2000
ACTIVITY	53	IS	12.6000
ACTIVITY	54	IS	6.6000
ACTIVITY	56	IS	5.3000
ACTIVITY	57	IS	7.2000
ACTIVITY	59	IS	11.0000
ACTIVITY	60	IS	6.3000
ACTIVITY	62	IS	5.6000
ACTIVITY	63	IS	8.2000
ACTIVITY	64	IS	3.0000
ACTIVITY	65	IS	12.2000
ACTIVITY	66	IS	4.4000
ACTIVITY	68	IS	5.7000
ACTIVITY	69	IS	8.1000
ACTIVITY	70	IS	3.7000
ACTIVITY	71	IS	12.3000
ACTIVITY	72	IS	2.4000
ACTIVITY	74	IS	5.7000
ACTIVITY	75	IS	8.1000
ACTIVITY	76	IS	3.7000
ACTIVITY	77	IS	12.3000
ACTIVITY	78	IS	26.0000
ACTIVITY	80	IS	6.3000
ACTIVITY	81	IS	8.4000
ACTIVITY	82	IS	.2000
ACTIVITY	83	IS	12.3000
ACTIVITY	84	IS	3.6000
ACTIVITY	86	IS	5.3000
ACTIVITY	87	IS	7.2000
ACTIVITY	89	IS	11.0000
ACTIVITY	90	IS	6.3000
ACTIVITY	92	IS	5.5000

ACTIVITY	93	IS	4.2000
ACTIVITY	94	IS	.3000
ACTIVITY	95	IS	7.0000
ACTIVITY	96	IS	6.3000
ACTIVITY	97	IS	3.1000
ACTIVITY	98	IS	6.2000
ACTIVITY	99	IS	3.0000
ACTIVITY	101	IS	7.2000
ACTIVITY	102	IS	9.1000
ACTIVITY	103	IS	2.7000
ACTIVITY	104	IS	5.0000
ACTIVITY	105	IS	2.8000
ACTIVITY	107	IS	6.4000
ACTIVITY	108	IS	8.8000
ACTIVITY	109	IS	7.8000
ACTIVITY	110	IS	10.3000
ACTIVITY	111	IS	5.5000
ACTIVITY	113	IS	9.0000
ACTIVITY	114	IS	6.0000
ACTIVITY	115	IS	9.4000
ACTIVITY	116	IS	13.0000
ACTIVITY	117	IS	6.0000
ACTIVITY	119	IS	10.9000
ACTIVITY	120	IS	6.1000
ACTIVITY	121	IS	7.0000
ACTIVITY	122	IS	13.2000
ACTIVITY	123	IS	7.0000
ACTIVITY	125	IS	11.2000
ACTIVITY	126	IS	6.3000
ACTIVITY	127	IS	4.3000
ACTIVITY	128	IS	10.3000
ACTIVITY	129	IS	6.9000
ACTIVITY	131	IS	10.9000
ACTIVITY	132	IS	3.7000
ACTIVITY	133	IS	4.3000
ACTIVITY	134	IS	9.6000
ACTIVITY	135	IS	6.9000
ACTIVITY	137	IS	11.2000
ACTIVITY	138	IS	.4000
ACTIVITY	139	IS	4.9000
ACTIVITY	140	IS	10.7000
ACTIVITY	141	IS	7.6000
ACTIVITY	143	IS	11.7000
ACTIVITY	145	IS	9.6000
ACTIVITY	146	IS	11.5000
ACTIVITY	147	IS	5.0000
ACTIVITY	149	IS	9.4000
ACTIVITY	150	IS	6.6000
ACTIVITY	151	IS	8.0000
ACTIVITY	152	IS	12.7000
ACTIVITY	153	IS	6.6000
ACTIVITY	155	IS	11.2000
ACTIVITY	156	IS	6.5000

PRICE RANGE OVER WHICH OPTIMAL SOLUTION HOLDS

		ACTIVITY LOWER BOUND	PRICE	ACTIVITY UPPER BOUND	PRICE
ACTIVITY	1	4	-18.1000	157	8.5000
ACTIVITY	7	10	-17.2000	158	8.5000
ACTIVITY	13	16	-16.1000	159	8.5000
ACTIVITY	19	22	-16.2000	160	8.5000
ACTIVITY	25	28	-15.4000	161	8.5000
ACTIVITY	31	34	-16.3000	162	8.5000
ACTIVITY	37	40	-15.8000	163	8.5000
ACTIVITY	46	43	-24.0000	164	.0000
ACTIVITY	49	52	-15.9000	165	8.5000
ACTIVITY	55	43	-14.6000	82	-13.7000
ACTIVITY	58	82	-22.4000	43	-21.7000
ACTIVITY	61	64	-14.6000	167	8.5000
ACTIVITY	67	72	-17.5000	168	8.5000
ACTIVITY	73	76	-18.6000	169	8.5000
ACTIVITY	79	82	-16.5000	170	8.5000
ACTIVITY	85	86	-19.2000	171	8.5000
ACTIVITY	88	****	-1	****	-1
ACTIVITY	91	94	-15.0000	172	8.5000
ACTIVITY	100	99	-24.9000	173	.0000
ACTIVITY	106	103	-23.1000	174	.0000
ACTIVITY	112	111	-25.7000	175	.0000
ACTIVITY	118	120	-23.1000	176	.0000
ACTIVITY	124	126	-25.4000	177	.0000
ACTIVITY	130	132	-21.5000	178	.0000
ACTIVITY	136	134	-23.1000	179	.0000
ACTIVITY	142	188	-24.2000	138	-22.3000
ACTIVITY	144	138	-24.6000	188	-22.7000
ACTIVITY	148	147	-23.5000	181	0.0000
ACTIVITY	154	156	-23.8000	182	.0000

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