ROADS OF RURAL AMERICA

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Six articles cover public policy issues, identify research needs in rural road transportation, suggest methodologies and report results of completed studies in rural road utilization. Jerry E. Fruin cites reductions in the real value of revenues for rural roads and highways and suggests three solutions: road abandonment, ad valorem fuel tax, and improved management. William Easter and Harald Jensen review the demand and cost estimation of transportation, especially as applied to older rural Americans. Malcolm Kirby, Peter Wong, and Wallace Cox describe and apply an optimizing network model for planning and analyzing transportation investments and, in an application to a timberwood product problem, showed a large efficiency gain over manual computations. Marc Johnson develops a surprisingly simple technique of benefit measurement for five types of incremental rural road improvement projects. From a court centralization experience in Michigan, Joseph Broder shows that centralization of services (bringing people to services) resulted in increased costs or reduced services to rural residents as compared to the services being distributed in local communities. Norman Walzer and Ralph Stablein review the condition of locally maintained roads and bridges in a region in Illinois, estimate costs to bring them up to standards acceptable to local officials, and discuss financial problems that may be encountered.

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PREFACE

We have built an elaborate road system that links virtually every household in the Nation with all other households, worksites, and marketing points. For the most part, these roads are public thoroughfares, built and maintained by tax dollars.

Rural America's road network permits producers to market crops expeditiously, move heavy machinery from field to field, and transport agricultural inputs to production sites. Equally important, it allows agricultural producers to dwell in suburban settings (with ready access to health care, education, and social interaction), while continuing to work and produce in the field.

Rural dwellers in the seventies have been much closer--in terms of travel time--to centralized services than were their grandparents. Then, rural road problems were chiefly conceived to be those of adequacy. A majority of all roads were either unpaved or only slightly surfaced. As vehicle size, weights, and numbers increased, the obvious solution to the adequacy problem consisted of upgrading and expanding existing roadways. Many observers continue to consider this to be the major problem and improving roads to be the major solution. There is merit in this view. Roads deteriorate. Studies show that a large number of bridges, drainage structures, road beds, and surfaces are substandard. It seems likely that this situation results both from natural deterioration of the structures and from increasing standards.

As the problem has been conceived to lie chiefly in the civil engineers' field, they have conducted and produced a majority of the available thought and literature.

Economists, with the exception of a few concerned with design, have tended to ignore the rural road issue. Recently, however, some students have developed new views concerning America's rural road problems. Principal components of these views are: (1) available public funds are proving insufficient to maintain existing highways and secondary roads, (2) roads should be tailored to users' needs, not arbitrary standards, and (3) the existing network is overdeveloped in some regions and underdeveloped in others. These and other related views are all founded in the economist's concern with resource allocation. Another set of views relates to appropriate sources of public funding for road construction and maintenance and equitable mechanisms for collecting these funds.

In this collection of studies we have attempted to present rather broad overviews of some of these new approaches to rural roads. These articles are intended to be useful to the road planning practitioner as well as to the scholar. They should help the reader understand rural road problems and demonstrate means of solving road planning problems. We hope that economists will be sufficiently intrigued by the number of unanswered questions these papers raise to undertake both theoretical and empirical inquiry into the rural road question.

CONTENTS

ISSUES IN RURAL ROAD MANAGEMENT

Jerry E. Fruin 1/

INTRODUCTION

An adequate road system is essential for the economic and social well-being of the U.S. rural population. The typical rural family relies on the road system for essential communication between town and city service centers. Children are bused to school. Farm produce is shipped, farm supplies are delivered, and repair parts, groceries, and household supplies are purchased many times throughout the week. Many vehicles, such as school buses and milk trucks, require year-round accessibility. Many rural families have one or more members who commute to factory or service jobs just as regularly as families who live in the cities. It is neither possible nor desirable for rural families to live in isolation.

Technological advancements have imposed the need that rural residents have better and safer roads. Faster speeds of passenger vehicles require smoother road surfaces for easy control and wider roads and intersections for safety. The heavier weights of vehicles require stronger roadbeds and bridges. Many rural roads do not meet reasonable standards for today's use. Other roads, adequate now, will deteriorate if funds are not available for required maintenance.

Rural America's road network is approaching a crisis in many areas. Roads are deteriorating, maintenance expenses escalate because of inflation, and maintenance and new construction funds are decreasing.

These are symptoms, however, not causes, of rural road problems. To find solutions, one must look beyond the symptoms to the causes:

1. The number and mileage of rural roads in many areas is excessive because of technological advances in transportation, agriculture, and related industries.

2. The traditional methods of funding rural roads cannot keep pace with inflation--especially if programs to reduce gasoline consumption are effective. This situation, intensified by the increased size and specialization of trucks, necessitated higher standards for road capacity and safety which resulted in increased construction and maintenance costs per mile of road.

3. Regulations and policies affecting rural roads are made at all levels of government to accomplish a multitude of objectives ranging from weed control to national defense. These policies, seldom optimal, can conflict and often work at cross purposes. The impacts of these three causes are not necessarily independent, nor limited to rural roads. They will be discussed, however, from the perspective of rural transportation policy.

1/ Jerry E. Fruin is an assistant professor of agricultural and applied economics at the University of Minnesota.

The Number of Rural Roads

There are too many rural roads in some areas. The situation is analogous to that of the railroad industry where too many low-density branch lines have been one of the causes of financial problems (1, 7,). 2/ These railroads were built to provide transport throughout the countryside prior to the development of motor trucks. The rural road system, too, was generally in place before the development of motor vehicles.

The network of roads, at 1-mile intervals in most farming areas in the Midwest, was developed for horse and buggy transportation. When the roads were initially laid out, they were narrow, requiring little land. If the Midwest territory were being settled today, the rural road system would be designed to accommodate larger farms and motorized transportation. It would be reasonable to place roads at least 2 miles apart so that "sections" would consist of at least 4 square miles. This would allow the same accessibility to a 320-acre farmstead as 1-mile intervals allow to 160-acre farmsteads, but would require only half the road mileage. Farmland per square mile would be increased by 4 acres if the eliminated roads had the minimum 33-foot right of way. The maximum that one-way distances would increase under such a system is 2 miles or 2 to 6 minutes' driving time, depending on the type of vehicle. A horse and wagon would generally take 20 to 30 minutes for an extra 2 miles.

A major cost of any transportation system is the opportunity cost of the resources committed to that system. These resources include the land required for the roadbed and right-of-way, the capital costs of physical structures, such as bridges, culverts, and road structures, and the capital goods committed to annual road maintenace.

The solution for areas with excess road mileage is obvious, although the method may not be. The number of rural roads should be reduced. This would return valuable farmland to production, reduce current expense on roadway maintenance, and require fewer expensive structures, such as bridges, culverts, and railroad crossings to be maintained and eventually upgraded or replaced. Safety would be improved as hazardous areas, such as intersections and railroad crossings, are reduced.

Local officials, to obtain these benefits, must determine the road requirements necessary for reasonable access and convenience and develop systematic plans for reducing the road network to that level. Such plans should consider current and prospective traffic patterns, homestead and business locations, and the design and condition of roadbeds. Other considerations include the age, condition, and weight or size restrictions on bridges and viaducts, as well as road safety hazards, and the costs and problems of converting roads to alternative uses.

Adequate access must be furnished to existing homes and businesses not on the final road system. This could be done by providing and maintaining, at public expense, private drives to existing structures as long as residences or businesses remain and by providing easements over the to-be-abandoned roadways to any unoccupied parcel that would become landlocked. Rights to public maintenance would end when the existing use was terminated. A change in property use that required an increase in maintenance expense would be allowed only if the property owner relinquished his or her rights to public maintenance. Compensatory payments to injured landowners might be necessary in some cases. The advantage in building certain new roads to eliminate poorly located existing roads should also be considered.

2/ Underscored numbers in parentheses refer to items in literature cited at the end of this article.

Financing Rural Roads

Traditional highway funding sources are gasoline taxes; vehicle and operator licenses; and general taxation, primarily the property tax. Revenues from the first two sources do not increase as a result of inflation. Unlike the receipts from a general sales tax which will increase as the same quantity of goods is sold for more money, the gasoline tax is based on physical volume.

The national weighted average of State gasoline taxes collected increased from 7.0 cents to 7.7 cents or 10 percent per gallon between 1970 and 1975, while the average price of regular gasoline in the United States, including taxes, rose 64 percent from 36 cents to 59 cents per gallon (8). State and Federal tax as a proportion of the selling price declined from 31 percent in 1970 to 20 percent in 1975. Total State and Federal gasoline tax collections rose only 28 percent in this time period, from $10 billion to $12.8 billion, while the highway construction cost index increased 62 percent. Total gasoline tax collections actually decreased for a time following the energy crisis because of decreased gasoline consumption.

Traditionally, the major sources of increased gasoline tax revenues were increased travel, higher tax rates, and decreasing automobile fuel efficiency. Total automobile miles driven have increased phenomenally since World War II because of such factors as higher incomes, population growth, better automobiles, and improved roads. This increase in miles driven was the primary cause of greater gasoline tax revenues. However, until recently, gasoline consumption (and taxes) increased even faster than the number of miles driven. Miles per gallon decreased as a result of the public's desire for heavy, powerful cars and of governmental requirements to meet pollution control standards. The efficiency of the average automobile dropped from 14.95 miles per gallon in 1950 to 14.28 miles per gallon in 1960 and to 13.29 miles per gallon in 1973.

This trend was curtailed when auto manufacturers responded to governmental mandates for better gasoline mileage for 1977 and later automobiles. One stated goal of President Carter's energy program is to reduce gasoline consumption 10 percent by 1985 (2). High gasoline taxes, while one of the proposals, are to be used for various tax rebates, but revenues are not earmarked for highways. The gasoline tax revenues available for rural roads may decrease even more if the energy program is successful.

Other forms of highway-oriented fees and taxes, such as drivers' licenses and auto and truck licenses, usually stated in fixed dollar amounts, are not likely to increase with inflation. Many of these fees are fixed by legislative action, and attempts to obtain significant increases frequently encounter fierce opposition and lobbying from the affected user groups (who generally are the primary beneficiaries of road and highway expenditures). Total vehicle and operator license fee collections increased only 38 percent between 1970 and 1975 (4).

The major inputs to new or improved roads are generally rising in dollar cost as fast as or faster than inflation. Asphalt, whose basic cost is based on crude oil prices, is an example. However, the costs of major expenditure classifications, such as construction equipment and structural steel, have also been rising faster than general levels of inflation. Thus, the Federal Highway Administration's highway construction cost index increased from 125.6 in 1970 to 203.8 in 1975 (8).

Observers have expressed concern that the revenues historically used for roads may be diverted to other uses. The idea of "highway trust funds" composed of gasoline tax receipts and highway user fees and dedicated to road construction and maintenance was for many years nearly inviolate. This concept, in recent years, has come under increased criticism. Proposals have been made, with some success, to have these traditional highway funding sources viewed as "a transportation trust fund" which could be tapped to fund various proposals from bikeways to mass transit systems. This is not necessarily bad, as many of the proposals have merit and are for complimentary forms of transportation. An adequate transportation plan, however, should ensure that sufficient funds are available for rural roads. This is especially important because of the dependence of county and township roads on property taxes.

Local roads have generally been heavily supported by property or other local taxes, although the situation varies by State. This is not true for the interstate system and most State highway systems, which have been built and maintained by gasoline taxes and license fees.

Federal policy has encouraged the use of State fuel taxes for highways since the twenties, and the Highway Revenue Act of 1956 assigned the Federal fuel tax and the excise taxes on automobiles, parts, and tires to the Highway Trust Fund (5). Local highway user revenues, however, fall far short of covering local highway expenditures.

Local governments spent more than twice as much on highway construction and maintenance as they received in user revenues and from their allocations of State and federally imposed user taxes in 1975. Total State and Federal highway user revenues and highway expenditures, in contrast, were about in balance (4). A detailed review of the total revenue requirements for city versus intercity roads might reveal that the greatest unfunded needs are in the rural areas.

One way for revenue changes to approximate the general level of inflation would be to convert the gasoline or fuel tax to a sales tax based on dollar sales, not gallons. One approach would be to establish a gasoline sales tax to approximate the current revenue levels from the per gallon tax. Rate increases, if desired, could be programmed for the next several years as part of the national program to reduce dependence on petroleum imports. The advantage of taxing gasoline on dollar sales is that the revenue per gallon from such a tax would increase at the same rate as the pretax gasoline price without requiring any legislative action.

Policies Toward Roads and Rural Transportation

Conflicts result concerning the objectives of the rural road system and how they should be achieved because of the many governmental jurisdictions and the multiple funding sources. Coordination between Government and adjacent jurisdictions is often lacking. A common example of this lack of coordination is network discontinuities, such as a 9-ton all-weather road connecting with a 5-ton road at a country or township line.

Less obvious examples would be how stringent construction, safety, or even funding requirements imposed by higher level governments can limit the options of local governments, causing the construction of fewer roads and bridges than would be possible under more flexible conditions. Thus, it may be necessary for a county to replace a structurally sound but low-clearance bridge to receive State aid when rebuilding a road. This might be the result of State policy aimed at upgrading all State aid roads to given standards, such as those established for the Federal system. This objective, however, might conflict with the need of the county to overlay many miles of deteriorating roads which have bridges with adequate clearance or with the need to replace an unsafe bridge on a good road.

Construction decisions requiring large capital outlays such as bridges, right-of-way purchases, and upgrading roadbeds need to be made by conscious choice not solely the result of regulation. Regulations pertaining to road weight limits and their enforcement at the local level may not be effective in obtaining maximum road use. Dense commodities, such as grain, milk, and fertilizer, must be hauled over rural roads. Recognizing this, any vehicle is allowed to travel on rural roads as long as it meets basic axle weight and total weight restrictions. It might be better if heavy vehicles were more closely controlled on rural roads as to weight, type, and possibly purpose.

One way to compare the potential damage caused by different vehicle sizes, axle configurations, or load limits is to compute the cumulative number of a "9-ton axle stress unit" used to move a given tonnage of a commodity. Transporting a given quantity of grain with farm tractors and 300-bushel trailers will do only about one-sixth of the damage to flexible pavements as hauling the same amount of grain in fully-loaded 800-bushel semitrailers (9).

Roads deteriorate from weather as well as use. A bituminous roadway's lifespan is limited even if the road is never used, so being too restrictive on utilization also can be futile. A road, however, receives little permanent damage from moderate overloads, provided that these occur infrequently. The best strategy may be a road construction system with relatively low load limits and use of a permit system for judicious movement of overweight loads (9). This would be advantageous if the reduction in construction costs exceeds the sum of any increased maintenance and administration costs after appropriate discount factors are applied.

The national trend of increasing the maximum weight limits on the interstate system (20,000 pounds per axle and 34,000 pounds per tandem axle), which has been done in several States, should be a cause for anxiety to rural road managers. The provisions of the Federal Aid Highway Act of 1956 effectively established weight limits of 18,000 pounds per single axle, 32,000 pounds per tandem axle, and 73,280 pounds overall (1). Rural road systems have been designed to meet these rulings.

The standard all-weather road is a "9-ton road," capable of supporting an 18,000-pound axle or a 32,000-pound tandem axle. There are two reasons for concern. First, is flexible pavement damage that can be caused by unauthorized interstate trucks making only a few trips. Increasing the load from 18,000 to 20,000 pounds on a single axle and from 32,000 to 34,000 pounds on a tandem axle will increase damage to pavements 50 and 25 percent, respectively (6).

The potential cost of upgrading rural roads to 10-ton limits is the second reason. Upgrading, while inevitable as competitive pressure mounts, will make the 10-ton limit an actuality. Thus, there will be added costs for road construction and maintenance on authorized feeder routes. Bridges that are structurally sound for 9-ton axles might not be safe for 10-ton axles. They might need to be "posted" and added to the list of "substandard" bridges needing replacement. Minnesota is one State where this change would increase the number of weight restriction postings from 3,090 to 3,801 on the 13,216 bridges that are 20-feet long and over (6).

CONCLUSIONS

Three ways exist to relieve the financial pressures on rural roads. First, rural transportation planners should recognize the need for reducing the total mileage of rural roads where excessive. This would reduce annual operation and maintenance expense, free land for agricultural production or other appropriate uses, improve road safety by reducing intersections, and allow funds for new construction and upgrading to be concentrated on the remaining roads. The result will be fewer but better and safer roads to meet the needs of rural America.

Second, fuel taxes should be increased to help achieve the Nation's energy conservation goals. However, the tax should be levied on the dollar value of gasoline sales rather than on the units sold so fuel tax revenues can keep pace with inflation. Increased fuel taxes, from the perspective of rural transportation, should be viewed as a revenue source to replace property tax and general fund expenditures on roads. If the fuel tax, at the national level, is imposed as part of a policy to reduce petroleum consumption, it is reasonable to use the increased receipts from such a tax for transportation methods other than highways if such uses would further reduce petroleum consumption.

Finally, more analysis is needed of the effects of different regulations and policies on the costs of road construction and maintenance. Although change may be necessary, the large investment in the existing physical plant of our rural road system should be wisely used. To do this will require coordination and planning by local, State, and Federal authorities for such things as load limits, design standards, and financing. Greater emphasis must be placed on coordination if we are to realize the benefits of the first two recommendations and be truly effective in managing the Nation's rural road system.

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TRANSPORTATION FOR OLDER RURAL AMERICANS: DEMAND AND COST ESTIMATION

K. William Easter and Harald Jensen 1/

INTRODUCTION

This article is a guide for transportation planning in rural areas with particular emphasis on the elderly. The problem of demand estimation is considered and transit costs are analyzed, as are the types of services and area served related to the cost and demand analysis.

The major objectives of the Older Americans Act of 1965 are to "maintain maximum independence and dignity in a home environment." A principal barrier to achieving these objectives is the lack of personal mobility for older Americans. Over 1,500 proposals have attempted to meet the national needs of older Americans. Some have met with success while others expired after the expiration of funding. The Senate Subcommittee on Rural Development has found no sound basis for confident conclusions about the financial viability of rural transportation (8). 2/

The increasing cost of owning and operating a private car, along with the reduction in rural transit services and continued out-migration of younger Americans all contribute to the rural transit problem. Many older people cannot depend on children for transportation. Lower income families and older Americans may not be able to own or operate a private car. And, rural bus and taxi services continue to decline or at best hold their own.

DEMAND

Demand or ridership estimates are important for planning rural transportation system. One must know who will use the services, at what price, and how often. The demand will vary depending on the type and frequency of service provided. Demand analysis can involve counting the number of people actually using a transit system or it can be based on assumption and prediction and involve a survey to determine who might use a system if installed.

Demand is often confused with need. Demand for transportation may be defined as the various quantities consumers are willing to purchase at alternative prices, other things being equal. The quantity purchased is affected by a number of circumstances, the more important being the price of the good or service, tastes and preferences, income, the number of consumers, and the prices of related goods or services. The

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1/ K. William Easter and Harald Jensen are professors of agricultural and applied economics at the University of Minnesota. This research was supported by funds from Title V of the Rural Development Act of 1972. Revised Jan. 1978.

2/ Underscored numbers in parentheses refer to items in Literature Cited at the end of this article.

quantity taken typically varies inversely with the price charged. The definition refers to an entire schedule or demand curve with a negative slope.

Need is not as easily defined. Need is essentially a subjective concept, which refers to a requirement for something essential or desirable that is lacking. A teenager "needs" a motorcycle or a senior citizen's club "needs" a bus for transportation to a concert. One cannot develop a schedule of needs or assign a numerical value to these needs which will be acceptable to everyone.

Even though "demand" is a more workable concept than "need," it may not provide an adequate base for transportation analysis. If consumers have insufficient funds to purchase transportation at any price level, there is zero demand except at zero price. The idea that tastes and preferences and related goods and services influence demand implies that the consumer has a choice. Choice of transport, however, is severely limited in many rural areas. Can we, then, rely only on demand to guide transportation decisions in rural areas?

One possible approach to estimating potential ridership is referred to as latent demand (10). Latent demand provides an estimate of the new trips that would be made if a specific population received increased transport services. It involves estimating the demand for new transportation under the assumption of no substitution.

Two closely related procedures have been used to estimate latent demand. One, called "gap analysis," compares trip rates among individuals (10). The maximum latent demand is the difference in trips made by those who have an automobile and those who do not. These two groups are compared within strata, such as similar ages and incomes. The analysis hinges on locating two populations which are similar, except for the availability of automobiles.

An example of this type of analysis is shown in figure 1. Latent demand for a person age 30 is approximately five trips per week in this example. The difference between M_2 and M_1 is an estimate of the number of new trips a person will make if an automobile were available.

Mobility levels are measured in trips per person per day or week for all people in each income level. If the transportation is to be provided by a bus or a van, however, the gap should be measured for these specific vehicles. The demand for the use of an automobile may be quite different from that for a bus.

The second approach is almost the same as gap analysis. It involves obtaining the transportation "required" for a target population by subtracting the average number of trips made by a target population from the number of trips made by a "normal" population. Normal travel behavior and target population travel are estimated with surveys. The National Personal Transportation Survey conducted by the U.S. Department of Transportation is the most frequently used data for normal travel. Populations usually are grouped by place of residence, age, sex, income, size of household, dependence on others for transportation, ownership of automobiles, and availability of public transportation. Trips are categorized by purpose, cost, destination, and frequency.

Both the "gap" and "requirements" approaches rely on surveys to estimate travel response to additional transportation. Yet studies show that survey data do not predict actual use well (8). Problems arise because of seasonal variation (or other irregularities) in ridership, multipurpose trips, memory loss, and the representativeness of population surveyed. Finally, the whole question of unrevealed preference always exists in survey responses.

Figure 1

Trips per week by age

Note: Mobility Level 1 is for persons with no private transportation. Mobility Level 2 is for persons with one car.

Current transportation demand analyses tend to use dual-choice models when comparing a public transit mode with the automobile. Models, in some situations, are needed that have more than two choices; relevant choices may include car pooling, taxis, and automobiles, along with various modes of public transit. However, due to the scattered population, in many rural areas, the automobile may be the only existing mode to compare with proposed public transit and a dual choice model may suffice.

Such factors as reliability, safety, comfort, and convenience when estimating demand for transit, particularly for the elderly and the handicapped, are also important considerations. Thus, when analyzing alternative vehicle costs, one must consider how the demand for the services of the vehicle is influenced by its characteristics, such as ease of access, flexibility, and safety. The time and convenience involved in the use of the system will also have a significant impact on quantity demanded. The time cost involved in using the system can be considered as part of the transit system's price.

Both the time series and cross section demand models have been tried, with time cost as one of the variables. "Time series models explain travel by mode or all modes for a geographical region; cross section models generally involve city-pair data. The latter models are variations of gravity models, generally with little or no economic content. Often they simply attempt to explain total travel between city pairs in terms of variables with no obvious meaning and no policy implications (2)." An example of such a variable is the product of the cities' populations divided by the square of the distance.

The main weakness of the demand estimates for single modes is the failure to distinguish between cross and direct elasticities. Lave's models, which include more than one mode, show that the cross elasticity component is much more important than the direct elasticity component. Thus, failure to include competing modes is a significant drawback (2).

Cross sectional models may work better in rural areas, which have fewer alternatives, than in cities where alternatives are more numerous. Even though choice may be limited to two modes in many rural areas, the demand may have to be estimated by purpose. Watson found that the purpose of the journey requires a different hypothesis regarding the choice of modes (9). The time-cost trade-off hypothesis was satisfactory for commuters, while the social-recreational traveler required a different hypothesis. Commuters were primarily interested in dollar costs and relative trip time (that is a 10-minute wait for a 10-minute trip is a long wait but a 10-minute wait for an hour trip is not). The social-recreational traveler, in contrast, was concerned about mode convenience features and speed.

Where little or no demand information exists, a cross section demand model might be used which is based on a number of independent variables such as: D = f (explicit price, implicit price, as time or convenience, age, per capita personal income, population density, and employment) with separate demand functions for transportation to obtain food, capital goods, health services, or recreation.

The main obstacle is finding the necessary data to estimate the model and the problem of multi-purpose trips. One would need to find newly introduced systems in rural areas having similar purposes and modes. However, with the growing number of public transportation programs under Federal and State support, information and data are becoming increasingly available.

A pilot project to test the demand may be a good approach in rural areas where new transit systems are being introduced. A pilot system operated with a rented school bus and/or volunteer drivers should create a demand which can be used to plan the system based on actual use. The community using this approach may not be burdened with inappropriate capital equipment purchased based on a survey of what people said they would do.

MINNESOTA'S DEMAND FOR NONMETROPOLITAN TRANSPORTATION

Minnesota's transportation system is oriented toward the Twin Cities (Minneapolis and St. Paul). There is very little commercial transportation in western Minnesota, especially running north and south. Without a private car it is difficult to go from one small city to another in outstate Minnesota. Even within most nonmetropolitan cities, taxi or bus service is limited or nonexistent.

In response to nonmetropolitan Minnesota's apparent lack of transit services, a number of public transit systems have recently been established. For example, in Dakota County a system of vans, small buses, and volunteer drivers provide people with transportation for medical services, shopping, social activities, work, and nutrition programs. The program was established based on the request of older Americans and agencies in the county who felt that a demand existed for transportation for the elderly. After 4 years of operation, their judgment seems to have been a good estimate of demand.

A similar system was started in a tricounty area of central Minnesota in 1976. This system, too, uses vans to meet the transport needs for medical services, shopping, social activities, and nutrition programs. The program, initiated after a survey of over 5,000 senior citizens, showed transportation to be one of the region's two greatest needs. However, one cannot call the survey an estimate of demand. In fact, it may not differ much from the judgment decision made in Dakota County. Both transit programs were started with funds from Title III of the Older Americans Act.

Minnesota's other rural transit systems supported by Title III were designed and started with about the same lack of demand information as the two previously mentioned. In a few cases this has been fatal, while the others continue to operate. A system designed without demand information can be easily saddled with inappropriate equipment and capital expenditures unless started with volunteer drivers and/or rented vehicles.

Some of the demand estimation and planning problems of rural transit can be highlighted by the tricounty program. The use of the system varied considerably by month and purpose (table 1). Ridership during the first 2 months was low because the program was just starting. However, even in the last 6 months, the ridership varied over 100 percent for most purposes (medical services, social activities, and nutrition programs). The aggregate ridership did not vary as much as ridership for specific purposes because of different patterns in ridership for different purposes. Still, planning for a transit demand which varies by as much as 258 passengers per month, or 47 percent, requires some costly extra capacity or long waiting periods for passengers.

The tricounty program also raises another issue regarding public transportation demand in rural areas. Title III does not allow a project to charge fares; thus, transportation is essentially free and in certain areas the designation as a poor peoples' program discourages people from using the service. Had the program originally charged a fare, would more people be using the service? If we assume this, then the demand curve would have a positive slope over a certain price range, possibly up to 50 cents per trip.

PROGRAM COSTS

Cost analysis is the second major part of planning transportation systems. The problem, if the demand schedule is known, is to find the least costly method of providing the desired service.

The type of cost analysis depends upon the decision. For example, if the decision is how to plan a new transit service, then all costs are variable and must be considered in the analysis. However, if the decision is whether to continue service on just one route, then the decisionmaker needs to know which costs will be reduced by discontinuing that route. Some costs are fixed and will not change with reduced service, while other costs will decrease. The fixed costs, at least in the short run, include administrative overhead, annual wages, insurance, taxes, fees, and depreciation. The costs which vary include maintenance, tire replacement, oil, and gasoline. Driver costs are also variable unless a set number of drivers have contracted for an annual wage.

Under a fixed route system (that is, following a set route and schedule), miles traveled are increased only as additional runs are made on the same route, or as new routes are added. Unless the system is being used close to full capacity, an extra passenger has little or no effect on costs. In contrast, with a demand-responsive system, such as a taxi, the mileage and costs generally increase with the number of passengers carried, as more passengers generally mean more trips. For demand responsive systems, administrative cost may also be influenced by numbers of passengers calling for rides.

One of the problems associated with planning and charging fares for fixed route public transit systems is that, unless the system is operating at or near full capacity, the marginal cost (added cost) of another passenger is near zero. In dealing with a decreasing average cost service, attempts to cover the full operational

Table 1--Ridership for Tri-Cap senior citizen program, central Minnesota, 1976

Month	Reason for trip				
	Medical	Shopping	Social	Nutrition	Total
			Number		
January	24	149	11	27	211
February	25	223	11	99	358
March	28	425	59	69	581
April	39	424	21	78	562
May	29	225	22	255	531
June	40	240	38	198	516
July	27	242	34	203	506
August	41	194	52	225	512
September	84	219	92	108	503
October	53	246	129	197	625
November	55	364	41	213	673
December	34	255	28	98	415

cost with user fees will mean fees higher than marginal costs. Attempts to cover the full operational cost by fares may well eliminate most or even all potential riders. For example, when evaluating the possibility of public ownership and operation of a small private rural bus system, planners need to consider the marginal cost of an additional rider and the willingness of riders to pay. If the demand curve is D_2, marginal cost pricing requires a fare of OP_1 and a public subsidy of P_1P_2 (fig. 2). 3/

The transit system could charge fares P_5 and cover total costs with demand D_2, but the ridership would drop from Q_0 to Q_1. Total cost could not be covered at any level of ridership if the demand were D_1, as average cost is greater than demand at all levels. Still, society could justify operating the system if the total consumer surplus--P_3BC--is greater than P_3P_4FB (the cost not covered by fares). Thus, the triangle ECP_4 must be larger than triangle EFB. The fare based on marginal cost pricing would be OP_3 and the subsidy would be P_3P_4.

Two costs loom large in the design of a rural transportation system: driver costs and administrative costs. Together, they account for 83 percent of the cost of a two 11-passenger van system which in 1974-75 dollars represents a total cost of approximately $50,000 annually (4). Forty-seven percent of the systems cost is for administration, while 36 percent is for paid drivers. The depreciation on the vans accounts for only 6 percent of the costs, while gasoline represents about 6.5 percent.

Many rural transit systems designed for older Americans have relied heavily on volunteer drivers because of high driver costs. Half of the transit systems funded in Minnesota under Title III of the Older Americans Act used volunteers in 1977. The high administrative costs are due to the dispersed population and the resulting small size of rural transit systems. For example, the same administrative staff might be able to run four vans as well as two. With four, administrative costs drop to only 31 percent of the total costs, while driver costs jump to 47 percent.

A change in the cost of fuel does not have a major impact on the proportion of fuel to total program cost. If fuel costs were to rise from 54 cents to 75 cents per gallon, annual costs increase about $1,200 for each van and fuel costs account for 8.6 percent of the total cost of a two-van transit system.

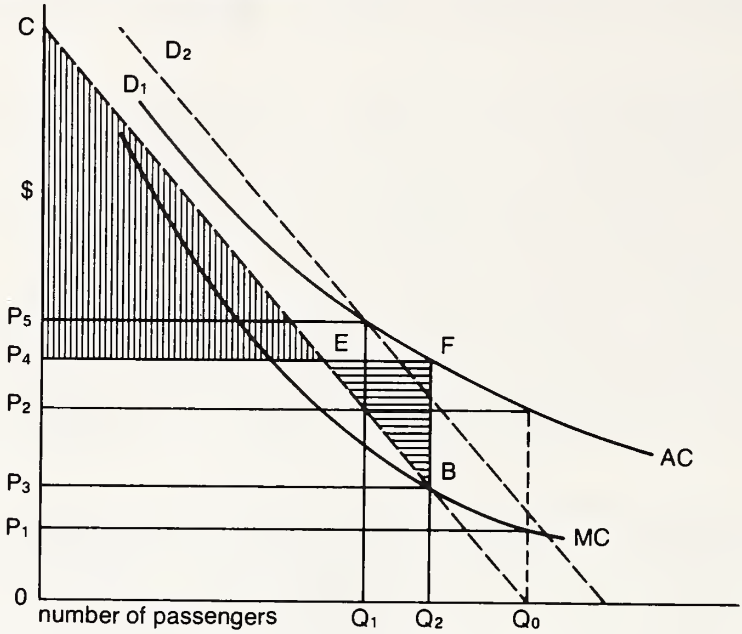
The least cost driver and vehicle combination will differ depending on the number of passengers. A volunteer-driver with an auto is the least cost alternative, if passengers average 3 per car or less. Once the system starts transporting 10 or 11 passengers per day, the 11-passenger van is the least costly combination. The school bus becomes the lowest cost alternative when ridership exceeds van capacity. The cost per passenger in a half-full 44-passenger school bus is just over 3 cents per seat-mile occupied, compared to 5 cents for volunteer drivers carrying three passengers, and 4.5 cents for a full 11-passenger van.

If the convenience factor is introduced, the school bus may not be as attractive as the van or the automobile. But when transporting 30 or more people on a fixed

3/ One method of financing such a system, suggested by Glenn Nelson, might be to charge all users of the transportation system a membership fee sufficient to cover fixed costs. Anyone can become a member regardless of income but the Government pays part or all of the membership fee for low-income people based on a sliding scale. User charges or fares are then based solely on marginal costs. These fares may also be subsidized for low income people. This system would potentially benefit everyone but its financing would be consistent with marginal cost principles. The membership fee could be a tax on residents of a geographic area so that all residents would be eligible to ride.

Figure 2

Cost and Demand for Transportation



route, the 44-passenger school bus with costs of 1.5 cents to 2 cents per mile is the most efficient from a cost standpoint. 4/

TYPE OF SERVICE AND AREA SERVED

The type of service and area to be served should be decided in conjunction with demand and cost estimates as they affect both cost and demand. First, is the service to be a fixed route, or will it be demand-responsive? The system might be a combination of these services with volunteer drivers picking up riders and taking them to fixed pickup points on a route traveled by a bus or van.

Second, will the service be provided for anyone who wants a ride or will it be only for older Americans who need health services or want to take part in a nutrition program? A system that does not restrict ridership has a much better chance of becoming viable in rural areas with widely dispersed population. If transportation is to be provided for work, then it must be every day at regular times except weekends. In contrast, transportation for health services would be needed less frequently.

The area or community to be serviced is another important consideration. Should the system serve a small city, the county, or even several counties? Total costs,

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4/ Cost data are available from a number of sources. In our study of Minnesota's rural transportation, we obtained data from school bus and commercial bus companies, the 3M van pool program, automobile dealers, community transportation systems, and a U.S. Department of Transportation publication.

both in dollars and travel time, will go up as wider areas are served. However, over a certain range of equipment and distance, the cost per passenger will drop as the area served is expanded and ridership increased.

Community and financial support both affect the area chosen to be served. For example, disagreements over how much of the cost should be subsidized by the city and how much by the county have caused the county to withdraw from providing possible transportation services in several areas of rural Minnesota. Rural transportation services tend to follow administrative boundaries, although certain parts of a county may not participate because people already have adequate transportation or do not favor additional public services.

If the system is to be designed to meet the needs of people who have difficulty going from their home to the vehicle, it will be necessary to buy special equipment and possibly provide escort service. These factors add to the cost of any vehicle, although for a bus, the cost will be prorated over many more passengers than for smaller vehicles.

CONCLUSIONS

Two of the more important considerations in the design and operation of a rural transit program are community participation and flexibility. Citizens using the system must be involved in planning and evaluating the transit program. If local tax dollars are to be used to support the program, the entire community should be aware of the costs and benefits. The program itself must be flexible enough to adapt to changes in demand for services. The program, which may start out in a small way under Title III funding, will have to adjust to a changing funding situation every year.

Some experimentation can be done in identifying demand for various transport services (health, nutrition, social, shopping, and commuting) and adjustments made as demands are identified and/or attitudes change towards public transportation. One way of beginning, with a relatively certain ridership, is to provide transit services to regular clients of social service agencies.

Finally, the community and those operating the system should agree at the beginning how performance should be measured. Should it be based just on the numbers of riders or on having the system self-sufficient after 3 to 5 years? The latter may well be unattainable as well as socially undesirable. A more reasonable alternative may be to keep the cost per passenger below some agreed-on level.

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OPTIMIZATION OF RURAL ROAD NETWORKS--AN APPLICATION OF THE TIMBER TRANSSHIPMENT MODEL

Malcolm Kirby, Peter Wong, and Wallace Cox 1/

INTRODUCTION

The Forest Service manages one of the largest rural road networks in the world, servicing about a third of the total land area. U.S. Forest Service land encompasses 226 million acres (914,000 KM^2), of which some 187 million acres (757,000 KM^2) are directly administered by the agency. The agency budgets about $350 million annually to construct 9,000 miles (11,200 KM^2) of rural roads. The largest single group of users of these roads are the transporters of wood products (1). 2/

The purpose of this article is to describe the general formulation of the Timber Transshipment Model. The model being developed by the Forest Service is used to analyze the shipments of logs and wood products over time and over alternative road networks and construction standards. The model can be adopted to complex problems involving multiple origins with either fixed or variable quantities to be shipped, multiple destination with either fixed or variable quantities to be received, multiple time period, raw intermediate or final products, and with options of timing, location, and quality of road construction and maintenance operators.

When analyzing problems involving transfer of logs from harvest sites to sawmills the objective of the model is to minimize combined loading, unloading, transportation, road construction, and road maintenance costs. When analyzing problems involving intermediate and final products the objective is to achieve maximum net revenue--gross revenue less the combined costs including mill processing costs. Application of the model is illustrated by a case study of the National Forest roads.

The model can be adapted to less complex planning situations. The problem for example, can be limited to one commodity and one time period. It could also be used for origins and destinations other than harvest, mill, or market locations with other kinds of traffic being substituted for shipments of wood products. Such adaptations usually make the problem easier to formulate because each limitation reduces the number of variables or constraints or eliminates the need for some types of constraints.

However, it is assumed that traffic between well-defined origins and destinations flows over a network predictably; namely so as to minimize the combined cost of travel and road investments. This assumption does not fit all rural traffic; in particular, it does not fit the traffic behavior of recreationists who tend to meander through forests. The first version of the model, for the single commodity case, is treated elsewhere by Kirby (2).

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2/ Underscored numbers in parentheses refer to items in Literature Cited at end of this article.

Shipments travel over the links of a road network; the links are joined at nodes. Beside road junctions, the origins and destinations are also called nodes. The variables that measure traffic flow are restricted by equations that require "conservation" of flow at each node. Such equations characterize Onden's transshipment problem (3).

Constraints pertaining to the movement of commodities from each supply node may take one of two forms: All of the supplies must be transported or a minimum amount must be transported. Constraints pertaining to the movement of commodities to each mill and market node may also take one of two forms: the demand must be satisfied exactly, or a minimum amount must be supplied to each mill and/or market.

Such restrictions are necessary, for example, to account for mills that are equipped to process specific timber species and therefore can be supplied by only a few sources. The amounts that are available are known, as are the maximum capacities of mills.

Supply nodes, in practice, usually correspond to one or a cluster of timber harvest landings, and demand nodes usually correspond to lumber mills or markets sometimes called appraisal points. Each supply node is the source of one or more commodities, such as logs suitable for processing into lumber or plywood. Similarly, each mill may produce one or more types of commodities, which may be final products or intermediate products. Unique commodity index numbers are used to show the differences in haul cost among commodities and also as a convenience in formulating constraints that restrict the flow of shipments, for example, from a given source to a mill.

We assume here that an empty truck returns along the same path that it used when it was loaded. We do so to avoid writing two flow variables for each link, one for each direction. Therefore, the unit transport cost accounts for two traversals, one in each direction. Any error introduced by this assumption is likely to be slight because the cost of a return trip is by far the smaller part of the total cost trip. We believe that this error is small enough to be disregarded in the light of the computational gains to be made.

A unit transport cost is set for each road link, and the cost of a trip is merely the collection of unit-transport costs--for the links that are traversed during the trip. Unit transport cost varies from link to link and is a function of road standard, the commodity being shipped, and the time period. Unit loading and unloading costs are set for origin and for destination locations.

Construction cost is defined as a fixed value, according to the road standard for each link. Where multiple road standards apply for a given road segment, each standard defines a separate link and a corresponding construction cost. Road maintenance cost is implicitly included in the transport cost and is allowed thereby to vary according to the traffic flow.

Our formulation is designed to permit the solution of large-scale network problems with many links and with many road construction and reconstruction projects. Two other models--Timber Transport (4) and (5) and Timber Roading RAM (6)--are not applicable because of their design characteristics: they both use a sample of routes that are calculated as a precondition to application in the model. The variables that correspond to flows along routes that join supply nodes to demand nodes are used to condition the construction project variables. The routes in the sample correspond to the first best, second best, and so on, up to a designated k-th best (where best usually means least travel cost). But as the number of all possible routes is enormous, as a matter of practicality only a few sample routes are calculated. Another reason for using a small sample is to limit the size of the optimization problem. For example, if we choose only five routes joining each of 30 supply nodes to each of eight demand nodes we would have 1,200 routes. And the more numerous the routes, the more expensive the computer costs. (This description oversimplifies these models but the conclusions still hold.)

The data requirements by time period are as follows:

- Unit transport cost for each link in the network,

- Construction cost for each road project,

- Amount of traffic generated at each origin location, either fixed or maximum amounts,

- Processing capacity of the mills and the corresponding constraints to account for the volumetric change at the mills, if any mills are included,

- Loading and unloading costs, if any, and

- Demand at each market location, either fixed or minimum amount.

MATHEMATICAL FORMULATION

The following formulation uses virtually the same notation used in an earlier study that treats the single commodity case (2). The text makes the mathematical expressions almost self-evident: constraint sets are defined for applicable ranges of subscripts and summations are taken over appropriate ranges. The index numbers, i,j,s, denote links of the network. The pair i,j denotes a connection between two nodes i and j; and s denotes the road link standard. If a new road can be built to more than one standard, or if an existing road can be upgraded, then each such standard defines a separate link. Let t denote the time period, and c and c' denote raw materials and finished products, respectively. Denote X_{ijstc} as the amount of commodity c that is shipped on link i j s (from i to j) during time period t, and S_{itc} as the supply of that commodity at a given supply node during the same period. Then corresponding constraints on supplies take one of the following forms, where V_{itc} is the amount of commodity c supplied at node i, time t:

$$\sum_{j,s} X_{ijstc} - \sum_{k,s} X_{kistc} = V_{itc}$$

$$V_{itc} \leqq S_{itc}$$

Analogous constraints can be written for supplies that span several time periods, several commodities, several sales, and the like.

Traffic is not restricted to predetermined routes; instead it is free to flow along any set of links. To assure that the volume of traffic leaving the sources of supply is equivalent to the volume arriving at destinations, we write conservation of flow equations for each node.

The constraint for a node that is only a road junction takes the following form for each period, for each commodity:

$$\sum_{i,s} X_{ijstc} = \sum_{k,s} X_{jkstc}$$

The equations for a node representing a mill, or a market, or both are somewhat more complex. A mill represents an intermediate stage in the flow of materials where raw materials are transformed into intermediate or final products. Intermediate products are shipped to a market. The transformation often engenders changes in the volume, the value, or the transport costs.

The number of truckloads of incoming logs, for example, is not necessarily the same as the number of truckloads of plywood shipped. To account for the volumetric change, we assume that the ratio of incoming to outgoing quantities is constant for a given choice of mill, time period, and pair of commodities (incoming and outgoing). Let $a_{jtc'}$ be the constant of proportionality. The index c', denoting a finished commodity, carries two identifications: the raw material and the resulting product (for example, Douglas-fir plywood). We wish to avoid the use of such cumbersome notation as hierarchical subscripts. Therefore, by carrying two identifications, we allow for more than one kind of raw material to be used to produce the same product and one material to be used to produce several final products, and for a material to be both an output from one mill and an input to another. Denote $Y_{jtc'}$ as the amount of finished commodity c' produced at node j, time t, and denote $D_{jtc'}$ as the amount of that commodity that is consumed at market node j, time t.

The following two general equations apply to a node that is a mill only, a market only, or both, by dropping the terms with $Y_{jtc'}$ for a market-only node, and $D_{jtc'}$ for a mill-only node. For incoming shipments of raw material, c that can be transformed into commodity c' at node j we have:

$$\sum_{i,s} X_{ijstc} = \sum_{c'} a_{jtc'} Y_{jtc'} + \sum_{k,s} X_{jkstc}$$

(An analogous equation applies to incoming finished materials that are used to produce a final commodity.)

The incoming quantity of a finished commodity c' and the quantity produced must be balanced by the quantity consumed by that market and the quantity shipped out to another market or mill:

$$\sum_{i,s} X_{ijstc'} + Y_{jtc'} = D_{jtc'} + \sum_{k,s} X_{jkstc'}$$

To conveniently formulate the cost of loading finished commodities at mill nodes, we denote $Z_{jtc'}$ as the positive difference between the amount of finished commodity c' produced and consumed during time t at a node that is both a mill and a market. Therefore, we require that:

$$Z_{jtc'} \geq Y_{jtc'} - D_{jtc'}$$

for all such nodes, and as we are minimizing cost, the left side equals the right side whenever the latter is positive and is zero otherwise.

Similarly for unloading, we denote $W_{jtc'}$ as the positive difference between the amount of finished commodity c' consumed and produced at node j that is both a mill and market. We require that:

$$W_{jtc'} \geq D_{jtc'} - Y_{jtc'}$$

Several options apply to constraints on demand. For example, whenever demand at a given market is a fixed value, $D_{jtc'}$ takes on a fixed value, and whenever demand $d_{tc'}$ spans several market nodes we have:

$$\sum_j D_{jtc'} \geq, = d_{tc'}$$

Analogous constraints can be written for demands that span several time periods, several commodities, several markets, and the like.

We assume that the quantity demanded does not exceed the quantity supplied, otherwise, the problem would have no feasible solution. If demand cannot be expressed explicitly, the constraints that pertain to demand are omitted. This is a common situation for national forest administrators.

The capacity of a mill to process might be limited during any given time period. It takes the following form:

$$\sum_{i,s} X_{ijstc} - \sum_{k,s} X_{jkstc} = V_{jtc}$$

$$V_{jtc} \leq b_{jtc}$$

where V_{jtc} is the amount of commodity c that is processed and b_{jtc} is the maximum capacity of a given mill to process a given incoming commodity during a given time period.

Road maintenance costs comprise both a fixed and a variable part, the latter depending on the type and amount of traffic. The fixed part could be associated with construction cost by defining artificial variables for existing links that correspond to construction variables for new links. In practice, such a formulation would employ a large number of integer-valued variables to account for a small part of the total cost. To avoid this complication, we assumed that maintenance cost is strictly proportional to the type and volume of traffic. Therefore, we included it as part of the unit transport cost.

The final part of the constraint set pertains to a conditional situation. If traffic flows across a road link ijs, that link must exist or it must be constructed. If it already exists, no construction cost is incurred. If not, it must be constructed and a construction cost is incurred. Denote Δ_{ijst} as a 0,1 variable that will take on the value 1 whenever road link is constructed during time period t and zero otherwise, and denote Q_{ijst} as a scale factor that relates the units of traffic flow to the dimensionless 0,1 variable. This scale factor may be interpreted as the capacity of the link for a given time period. The dual conditions, that flow across a road link requires the construction of the link, and that the absence of such construction prohibits such flow, take the following form:

$$\sum_c X_{ijstc} \leq \sum_{k=1}^{t} Q_{ijsk} \Delta_{ijsk}$$

Whenever more than one road standard or time period is defined with a road link for each standard for each time period the following constraint insures that such road construction projects are mutually exclusive:

$$\sum_{s,t} \Delta_{ijst} \leq 1$$

The next step is the objective function. Notations used for unit revenues and costs are: p_{jtc} is the revenue: l_{itc} is the loading cost at i, a supply node or a mill; u_{jtc} is the unloading cost at j, a mill or a market node; h_{ijstc} is the transport (haul) cost for commodity c, including the variable part of the road maintenance cost; c_{ijst} is the road link construction cost and m_{jtc} is the milling cost. Because unit values are defined by time period, we may assume that they are discounted values.

Milling cost, in practice, is a complex function of fixed charges and the volumes and blends of raw material and final products. But milling cost is a small part of the total cost, and our simple representation is consistent with a model that focuses on road investment decisions.

An optimal policy may be one of two types: minimum costs or maximum revenue less costs. Both types are expressed as a single objective function. The first is obtained by dropping the terms that pertain to revenue. The following expression could be simplified by collecting terms but to do so would be less instructive. The six terms pertain to revenue, loading cost, transport (haul) cost, milling cost, and construction cost, respectively. The objective is to maximize:

$$\sum_{jtc} p_{jtc} D_{jtc} - \sum_{itc} l_{itc} V_{itc} - \sum_{jtc'} l_{jtc'} Z_{jtc'}$$
$$- \sum_{jtc} u_{jtc} V_{jtc} - \sum_{jtc'} u_{jtc'} W_{jtc'}$$
$$- \sum_{ijstc} h_{ijstc} X_{ijstc} - \sum_{ijstc'} h_{ijstc'} X_{ijstc'}$$
$$- \sum_{jtc} m_{jtc} Y_{jtc} - \sum_{ijst} c_{ijst} \Delta_{ijst}$$

The formulation is general enough to include multistage processing; for example, situations in which logs are shipped to a mill where they are processed into lumber which in turn are shipped to another mill to be processed into finished products, such as building materials. The formulation also applies to situations in which mills are included but markets are not.

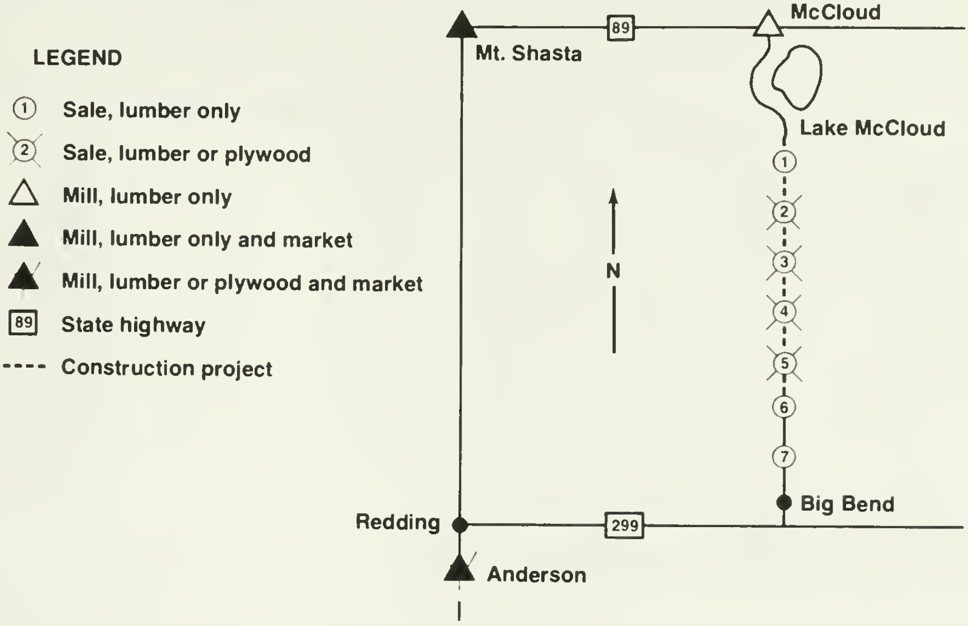
The following case study involves seven harvest locations, three mills, two markets, five road construction projects with two road standards each, four time periods, and four commodities. Not being a large scale example, it does not illustrate the power of the transshipment model. But it has the merit of being small enough so that it can be understood quickly and will, therefore, serve the needs of this article. A case study involving a more complex road network has been reported by Wong and Cox (7).

Illustrative Example

The Hawkins Creek Road, a 29-mile arterial road, winding through the McCloud and Shasta Lake Ranger Districts of the Shasta Trinity National Forest, connects California State Highways 89 and 299 (see figure). The road provides access to a large commercial timber area and to Lake McCloud, which has a large amount of recreation activity. Recreation travel costs are negligible compared with timber haul costs, although the recreation traffic is heavy.

To haul timber, however, a major or minor reconstruction would be required on each of five distinct sections. Heavy construction costs could be offset only by substantial reductions in corresponding timber haul costs. A major reconstruction would have high initial cost, but lower hauling costs. A major reconstruction would produce a good, single-lane road with turnouts and a crushed rock surface 14 feet wide.

Locations of Harvests, Mills, Markets and Road Construction Projects



Minor reconstruction, at a cost of $15,000 per mile, would include some widening, rock surfacing, slide removal, and some additional turnouts so that the road could accommodate the timber traffic that is projected over the next 20 years. These projects are independent of each other and may be scheduled at any time during the 20-year planning period.

Three mills are located in the area: lumber mills at McCloud and at Mt. Shasta, and a lumber and plywood mill at Anderson. Markets are located at Anderson and Mt. Shasta. Four of the timber sales can supply logs suitable for either commodity, and three sales can supply logs for lumber only.

We divided the 20-year planning period into four 5-year periods, and we expressed revenue and costs in terms of net present worth, discounted at 10 percent. A 10-percent discount rate is recommended by the President's Office of Management and Budget. Our objective was to find the combination of harvest amounts, harvest timing, road construction project schedules, and transport routes that maximize net present worth (revenue less costs), subject to constraints on harvest volumes and mill capacities (table 1). The annual mill processing capacity was limited to 48 MBF (million board feet) for Mt. Shasta and 97 MBF for McCloud. No capacity limit was set for Anderson mill. Plywood and lumber values are $345/MBF and $230/MBF, and their processing costs are $160/MBF and $75/MBF, respectively. For brevity, construction and haul cost data are omitted.

The optimal solution calls for minor reconstruction of all five sections during the first time period. The major construction cost exceeds the corresponding reduction in haul costs. The undiscounted net values, about $14 million dollars per period, represent a net present worth of $23.5 million over the 20-year period (table 2).

Table 1--Constraints on harvest amounts by period and commodity

Sale number	Commodity	Time period 1/				All periods
		1	2	3	4	
		Million board feet				
1	Lumber	55	55	55	55	55
2	Lumber and plywood	0	55	0	55	110
3	Lumber and plywood	0	2/20	0	20	40
4	Lumber and plywood	20	20	20	20	20
5	Lumber and plywood	2/35	0	25	0	60
6	Lumber	2/40	0	40	0	80
7	Lumber	30	30	30	30	30
	All sales	100	100	100	100	395

Note: Entries are maximum amounts permitted.
1/ Each period represents 5 years.
2/ Also the minimum amount permitted.

Table 2--Cost summary for the optimal solution

Revenue and cost	Time period 1/			
	1	2	3	4
	1,000 dollars 2/			
Timber revenue	23,000	23,000	23,000	21,850
Less hauling cost	-1,562	-1,163	-1,699	-1,329
Less processing cost	-7,500	-7,500	-7,500	-7,125
Less reconstruction cost	-123	0	0	0
Net value	13,815	14,337	13,801	13,396

1/ Each period represents 5 years.
2/ Undiscounted cost.

Table 3--Optimal timber harvest volumes, by period and commodity

Sale number	Commodity	Time period 1/ 1	2	3	4	All periods
		Million board feet				
1	Lumber	25	25	5	0	55
2	Lumber	--	55	--	55	110
	Plywood	--	0	--	0	0
3	Lumber	--	20	--	20	40
	Plywood	--	0	--	0	0
4	Lumber	0	0	20	0	20
	Plywood	0	0	0	0	0
5	Lumber	35	--	25	--	60
	Plywood	0	--	0	--	0
6	Lumber	40	--	40	--	80
7	Lumber	0	0	10	20	30
	Total volume	100	100	100	95	395

-- = Not applicable.
1/ Each period represents 5 years.

The optimal solution also calls for all available timber to be cut, which implies that sales 1, 2, 4, and 7 are not deficit sales (no minimum supply requirements apply to these sales) (table 3). All of the timber is to be processed into lumber and all cutting is to take place as soon as possible. All logs are first shipped to the McCloud mill for processing; the finished products are shipped to the appraisal point at Mount Shasta.

Sensitivity analyses to show uncertainty of costs and harvest volumes can be easily performed with this model by changing the values and resolving the problem. The cost of the computer run, $33, was insignificant compared to the size of the investments and revenues.

This small-scale example has important consequences. The harvest volume is about 5 percent of the total annual harvest of the Shasta-Trinity National Forest. This means that about 20 problems of similar size would account for the bulk of the annual timber-road program for this forest (one of the largest administered by the Forest Service). The combined expenditures for timber and road programs account for the bulk of all expenditures on the national forests.

CONCLUSIONS

The case study demonstrated some of the capabilities of the Timber Transshipment Model. In choosing whether to select a major road reconstruction project, the decisionmaker can use a corresponding linear programming problem for the harvest scheduling and haul route selection. There are 3,125 possible choices and, therefore, 3,125 linear programming (LP) problems in our case study. We manually solved one such

LP problem as a demonstration; the solution required about 2 man-days. At this rate, the manual computation of 3,125 LP problems would require 25 years to complete. Although an analyst can derive a good solution manually in less time, he could never be certain how close it is to an optimal solution.

From this application we can see that the model is well suited to transportation planning problems where reconstruction and new construction of many road segments are involved. Strategies to reduce computation time for large problems are described elsewhere (2).

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BENEFIT MEASUREMENT FOR RURAL ROAD IMPROVEMENT PROJECTS

Marc A. Johnson 1/

INTRODUCTION

Cost measurements for rural road improvements are readily available as estimates and bids of construction contractors. 2/ Benefit measurements, however, are elusive. The purposes of this paper are to identify characteristics of demand for rural roadway and bridge improvements and to design a measure of marginal benefits attributable to these improvements.

Rural roads and bridges are clearly public goods. Costs to restrict access to this vast network of roads prohibits individual user charges. Once roadways are built, individual trips by vehicles add imperceptibly to road maintenance cost. Rural roads can be used simultaneously by individual carriers of different types and serve to facilitate movement of people and commodities between rural and urban places as well as between rural places. Arterial networks serve to facilitate interurban movements of people and commodities.

Users or rural roads can be differentiated by time pattern of use and vehicle load mass (fig. 1). The time pattern of use can be continuous (daily, weekly), or seasonal or periodic (random and infrequent). Load mass, the gross weight of vehicle and its load, may be light (automobiles, service vans), moderate (feed trucks), or heavy (semi-trailer trucks, cement trucks).

MEASURING BENEFITS

Unless congestion occurs, numerous users may traverse a roadway without affecting one another. Consequently, benefits derived from roadway improvements are the sum of benefits derived by individual users of the road (2). 3/ Even where congestion currently exists, a project to reduce congestion yields benefits of reduced time and fuel use, which are additive among individual roadway users.

It is assumed, for purposes of this paper, that some roadway network exists. This permits one to disregard new land development and substantive changes in production

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2/ Costs of roadway improvements are composed of initial construction cost and the present value of continuous maintenance expenditures. Local decisionmakers, such as county or parrish commissioners, must give particular attention to the continuous maintenance responsibility before selecting a plan for road and bridge improvement projects.

3/ Underscored numbers in parentheses refer to items in Literature Cited at the end of this article.

Figure 1

Types of Rural Road Users

Time Pattern \ Mass	Light	Moderate	Heavy
Continuous	Residents Farm Workers Mail and News Service School Buses	Farm Trucks Feed Delivery	Logging Vehicles Mining Vehicles
Seasonal	Fertilizer Wagons	Farm Trucks (grain) Custom Work Vehicles	Semi-trailer Grain Trucks
Periodic, light	Pleasure Drivers Electricians and Plumbers Veterinarians	Hay Delivery Septic Tank Service	Semi-trailer Livestock Trucks Construction Vehicles (cement, lumber)

patterns resulting from new transportation alternatives. This assumption allows concentration upon projects representing improvements in the rural road network, namely, addition of links and link capacity expansion. The model can still be utilized, however, to evaluate the building of a housing development along a new or improved road as often occurs in urban fringe areas.

Benefit measurement can be treated similarly for five types of rural road improvement projects: (1) building a new roadway link, (2) replacing a missing or damaged bridge, (3) upgrading bridge weight limits, (4) widening a road, and (5) upgrading a road for all-weather access. The first two of these project types relate to adding (or restoring) links to the roadway network. The remaining project types improve link capacity.

All benefits attributable to these incremental roadway improvements can be accounted for in reduced circuity costs, and reduced inventory and deterioration costs of products ready for market. Relevant inventory and deterioration costs are incurred only when bad weather makes roads completely inaccessible to moderate and heavy mass vehicles. These costs are avoidable only for projects converting weather-susceptible to all-weather roads. Benefits to all other types of road improvement projects are accounted for solely in reduced circuity costs. For an individual roadway user, u, annual reduced circuity costs attributable to a project are measured by the following formula:

$$(1) \qquad P_u\ (A_1)\ [(P_t t + p_f f)_u\ dM_u]\ V_u\ R_{1u}$$

where $P_u\ (A_1)$ = probability of access by user u to the project roadway during the period of use,

P_t = value per hour of truck and driver time during the period of use (dollars/hour),

t = time used per route mile traveled (hours/mile),

P_f = fuel price (dollars/gallon),

f = fuel used per route mile traveled (gallons/mile),

dM_u = change in miles traveled for user u due to the project (miles),

V_u = number of one-way trips per year,

R_{1u} = 1 if user u's load is restricted prior to the project and unrestricted thereafter, and

R_{1u} = 0 if the load is unrestricted or unaffected by the project.

The definition of circuity cost used here will be modified in later equations for the cases in which congestion is reduced and weather susceptibility is removed. Several terms require explanation.

The probability of access to the road being improved, $P_u\ (A_1)$, is the probability that user u can get on the road on any chosen day to take advantage of the improvement. On all-weather roads, this probability is unity. On roadways with load restrictions during the spring thaw, the probability of access for large trucks is zero during spring and unity during other times. On roadways impassable after heavy rains, the probability of access is the ratio of the average number of days the road is usable during the period of use to the number of days in the period. Probability of access for seasonal traffic may differ from rainy to dry seasons. Consequently, probability of access differs between users because of differing periods of use and load mass.

The term in brackets, $(P_t t + P_f f)_u\ dMu$, is the trip cost of circuity avoidable by user u, after a proposed roadway improvement. When multiplied by the annual number of trips made by user u, V_u, a measure of potential savings in circuity costs per year--to the user, is derived.

Value of driver and truck time per hour, p_t, is a subjective measure depending partially upon period of roadway use and load mass. For example, in peak wheat harvest periods, opportunity costs of labor and equipment time are likely higher than in other periods. Similarly, opportunity cost of a unit of semi-trailer truck time is likely more than a unit of smaller truck time. When value of driver and truck time per hour varies over the year, trip circuity cost evaluated for each periodic value of p_t is weighted by the number of trips traveled in each corresponding period.

The term dM_u is reduction in miles traveled by a user upon a single, one-way trip, attributable to the road improvement. Measurement of dM_u is explained in detail in a later section.

The term R_{1u} permits differentiation among roadway users. Some types of projects affect only certain classes of users. Upgrading bridge weight limits is an example; moderate and heavy mass vehicles will benefit (R_{1u} = 1), while light mass vehicles will not be affected (R_{1u} = 0).

A stream of expected annual benefits is constructed for each user type with appropriate traffic growth and decline parameters. Each individual value stream is discounted to present value and these values are summed across all types of users. With expectations of constant traffic volume, an indefinitely longtime horizon and constant interest rate, r, aggregate benefits attributable to a rural road improvement project are measured as the value of a perpetuity, as:

$$(2) \quad \frac{1}{r} \sum_{u} P_u (A_1) \, [(P_t t + P_f f)_u \, dM_u] \, V_u \, R_{1u}.$$

APPLYING THE BENEFIT MEASURE

The benefit measure displayed in formula (2) is used somewhat differently to evaluate advantages associated with each of the five types of roadway improvement projects. When projects encompass improvements on more than one roadway link, benefit measures for each link can be incorporated into a sequential link analysis of an entire project (1).

Building a New Road

Benefits attributable to construction of a new road can be measured using formula 2 directly. If the road is to be all-weather, probability of access, $P_u (A_1)$, will equal unity for all users. If the road is to have some weather restrictions, $P_u (A_1)$, will be less than unity for at least some types of users. As no road previously existed, no one could traverse the link. Thus, R_{1u} equals unity for all types of users.

Reduced circuity for affected roadway users, dM_u, can be visualized in figure 2. Any improvement in the rural road network will affect movements to and from a relatively small area. The existing road grid in figure 2, is represented by solid lines and the town lies at intersection z.

A proposed road construction project would create a road over dashed link wz. The only users for whom the new road would shorten trips to town are those with trips originating or terminating on the hatched links of the grid. For a user moving to or from a location on the road for which the new road is an extension, such as location a, the shortest route is reduced from awxyz to awz. Thus, dM_u for such a user is equal to the distance represented by (wx + yz). This is the maximum distance savings any user could attribute to the construction project. For a user with trips to and from locations on a lateral connecting road, such as location b, the maximum distance savings is diminished by distance ε.

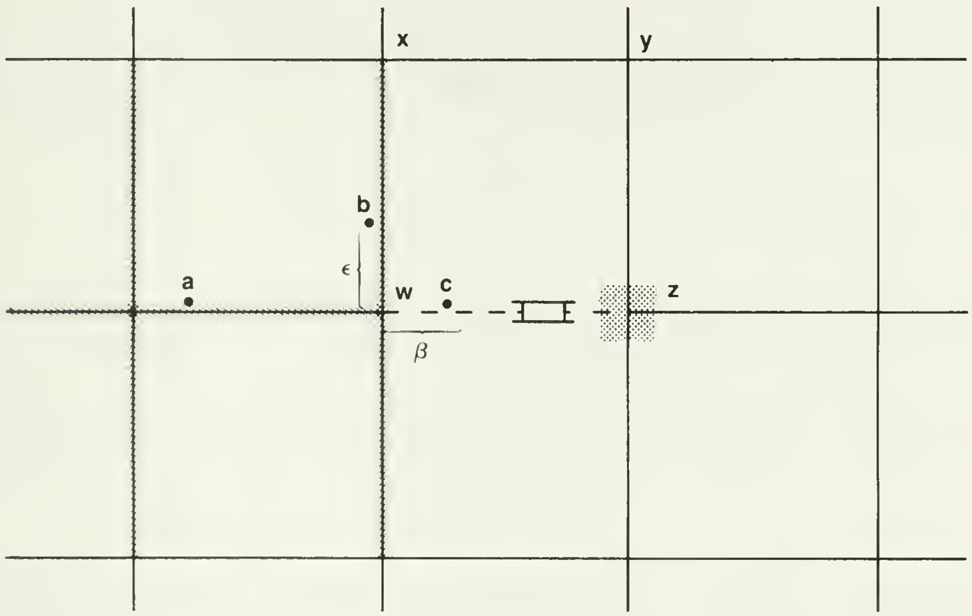
Replacing a Bridge

Measuring benefits attributable to a bridge replacement project differs only slightly from the preceding application. When a bridge is washed out or condemned, such as the one on link wz in figure 2, the entire link served by the bridge becomes impassible. The restriction term, R_{1u}, equals unity for all types of roadway users. Probability of access, $P_u(A_1)$, refers to the likelihood of using the roadway served by the bridge, not just the bridge itself.

Measurements of reduced circuity for movements to and from locations such as a and b, in figure 2, are similar to those previously discussed. For users with trips to and from locations on the affected road, such as location c, reduced circuity is calculated as (β + wx + yz), where β is the distance one must backtrack to reach the usable road.

Figure 2

Roadway Grid



Upgrading Bridge Weight Limits

A project to replace a 5-ton bridge with a 30-ton bridge can also be evaluated using formula 2. The probability of access, $P_u(A_1)$, again refers to the likelihood of using the part of the road served by the bridge. Change in circuity, dM_u, is calculated as it was for bridge replacement. The critical difference lies in the value taken by the restrictions term, R_{1u}. For light mass vehicles $R_{1u} = 0$, vehicles of less than 5 tons will be unrestricted on the current bridge structure. For moderate and heavy mass vehicles $R_{1u} = 1$, the new bridge will permit use of road wz by these vehicles where the road is unusable with the old bridge.

Widening a Road

Evaluating a project to widen a road requires some modification of formula (2). A road is considered for widening from 2 to 4 lanes when congestion slows the flow of traffic. Consequently, increasing vehicle capacity of the roadway by adding lanes changes rates of time and fuel consumption for vehicles using the road. Formula (2) can be modified to evaluate addition of lanes as:

$$(3) \quad \frac{1}{r} \sum_u P_u(A_1) \; [(P_t \; \Delta t + p_f \; \Delta f)_u \; M'_u] \; V_u R_{1u}$$

where Δt = change in time used per mile traveled (hours/mile),

Δf = change in fuel used per route mile traveled (gallons/mile),

M_u = previously congested miles traversed by user u.

Probability of access, $P_u(A_1)$, depends upon whether the subject road is of all-weather quality. As the speed of traffic flow affects all traffic similarly, $R_{1u} = 1$ for all types of roadway users.

<u>All-Weather Roads</u>

If a road is to be converted from weather-susceptible to all-weather quality, formula (2) must be modified. The cost of circuity for individual trips is unaffected. The probability of access is improved from something less than unity to unity. Benefits can be measured as:

$$(4)\ \frac{1}{r} \sum_u [1-P_u(A_1)]\ [(P_t t + P_f f)_u\ dM_u]\ V_u\ R_{1u} + [1-P_u(A_2)]\ i_u V_u R_{2u}$$

$$(5)\ R_{1u} \cdot R_{2u} = 0$$

where i_u = daily inventory and deterioration cost of product (dollars/load volume/day),

$P_u(A_2)$ = probability of access by user u to any road,

R_{2u} = 1 if user u's load is restricted from use of any road prior to the project and unrestricted thereafter, and

R_{2u} = 0 if the load is unrestricted or unaffected by the project.

The term $P_u(A_1)$ represents the probability of access to the project road link by user u before the improvement. Thus, savings from reduced circuity are weighted by the change in probability of access, $[1 - P_u(A_1)]$, for the improvement reduces circuity only on bad weather days.

Upgrading roadways to all-weather quality may also prevent losses. Avoidable inventory losses are measured by $[1- P_u(A_2)]\ i_u V_u R_{2u}$. The term $P_u(A_2)$ is the probability that user u has access to at least one road on any chosen day. 4/ When $P_u(A_2)$ equals 1 the probability weight $[1 - P_u(A_2)]$ equals zero, canceling any benefits from avoided inventory losses. Probability $P_u(A_2)$ fails to equal unity only for users with trips to and from locations on a weather-susceptible road.

Consider a project to convert roadway link wz (fig. 2) from a weather-susceptible to an all-weather road. Assume all other roads on the grid are all-weather roads. Users with trips to and from locations a and b will experience additional circuity costs on bad weather days before the improvement, but can reach town. Thus, for these users $P_u(A_2)$ equals 1 and R_{2u} equals 0. However, for users with trips to and from location c where no access to any road is possible on bad weather days, $P_u(A_2)$ is less than 1 and R_{2u} equals 1. Condition (5) guarantees that before the improvement, while product is restricted in inventory, increased circuity costs cannot be counted.

CONCLUSIONS

The analyst measuring benefits attributable to rural road improvement projects must be familiar with traffic origins, destinations, volumes, and composition. Vehicle counts alone do not permit enough analysis to order project priorities economically. Knowledge of rural agricultural, resource production patterns, and residential locations yield an understanding of traffic origins, destinations, and

4/ The broader nature of this term means that $P_u(A_2) \geq P_u(A_1)$.

composition. Selected rural area traffic studies would be useful in determining traffic composition.

Valuing driver and vehicle time is the most difficult part of benefit measurement. Calculations can be simplified by attaching a single, average value to each user of a particular type. By this method, all passenger trips would be assigned one time value per mile and all semi-trailer truck trips would be assigned another time value per mile. Investigation to determine appropriate time valuations and differential seasonal time valuations for types of roadway users would improve the accuracy of benefit measurement.

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BRINGING SERVICES TO PEOPLE VERSUS BRINGING PEOPLE TO SERVICES

Josef M. Broder 1/

INTRODUCTION

This article identifies, describes, and evaluates impacts which physical location of public service delivery systems in general, and court location in particular, have on the associated travel and waiting time costs borne by citizens using community services. Michigan's court centralization and consolidation experience serves as the example for discussing rural community service delivery issues.

For the nearly 3 million households outside Standard Metropolitan Statistical Areas (SMSAs) with no available automobiles, and for automobile owners faced with higher fuel prices and fuel taxes, the issue of bringing services to people versus taking people to services assumes primary importance (6). 2/ Central to this issue is a better understanding of how alternative structures of community service availability and delivery systems affect rural areas' ability to meet service needs.

Equal Protection and Court Location

As many small decentralized rural courts are replaced by centralized, consolidated, and professionalized courts, rural residents have become concerned over the increased time and travel burden created by these nationwide reforms and over how physical separation from court location affects costs of providing local police protection. Whether rural residents are being denied "equal protection of the laws" as guaranteed by the Fourteenth Amendment to the U.S. Constitution has become a fundamental issue.

THE MICHIGAN EXPERIENCE

Michigan abolished the decentralized justices of the peace in favor of a statewide system of district courts in 1969. The main components of the 1969 reform included:

(1) Court consolidation with respect to number of courts in the jurisdiction and types of cases heard,

(2) Court centralization with respect to court location and financing, and

(3) Court professionalization--requiring that all judges be attorneys, setting standards for holding court, and removing the fee system of judicial compensation.

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2/ Underscored numbers in parentheses refer to items in Literature Cited at the end of this article.

Local court centralization can be viewed as part of the reformists' philosophy of local government which argues that decentralized Government tends to be fragmented, inefficient, and wasteful (1). Community services, it is argued, can be improved only by consolidation of governmental units and expansion of the service delivery process. Largely ignored by consolidation and centralization advocates are differences in effective demand for community services and problems of local accessibility to centrally dispersed services.

Local residents, attempting to choose alternative structures of court service, expressed dissatisfaction with the cost, quantity, and quality of court systems. Michigan State University's research project focused specifically on the share of centralized court costs being paid by rural citizens (2). Obvious costs, known at the time reorganization efforts were approved, included those of operating the district court system. These costs, financed out of State and county budgets, included salaries of judges and court personnel, and maintenance of court facilities. Rural residents share this cost as taxpayers.

Another cost impact, one not publicly debated at the time reorganization measures were being considered, involved court utilization costs or the amount of resources required to use centralized court services. From a marketing perspective, the costs of moving people and/or resources are generally known as assembly costs. Court utilizations costs for rural residents are based on court accessibility which consists of two main components: time and location.

So that costs of people moving to centralized courts could be measured, the reorganization experience of Jackson County, Michigan was studied. Jackson County, with a 1970 county population of 143,274 and a central, county-seat city population of 45,484, is believed to typify the demographic characteristics of many rural counties in Michigan and other States.

Prior to the 1969 reorganization, State statutes up to 1969 allowed as many as two justice courts in each township, the lowest level of local Government in rural Michigan. Between 1965 and 1969, Jackson County's 19 townships used services of 15 geographically dispersed justices of the peace who heard minor civil disputes and minor ordinance and statute violations from local county and State policemen. The 1969 reorganization abolished these 15 justice courts and replaced them with a centrally located district court staffed by two full-time professional, salaried judges.

Questionnaires mailed to former justices of the peace and personal interviews of local police chiefs measured costs of using the centralized court. The more obvious costs involved reduced accessibility with respect to time. Being located at home or a place of business and given their large numbers, justice courts were accessible at most any time, including evenings, weekends, and holidays. Reorganized counts, with two judges, could not maintain this level of accessibility. Data limitations, however, precluded the measurement of costs to local residents or police resulting from decreased time in accessibility.

The second component of court utilization costs was created by reduced locational accessibility. Primary attention in measuring these costs was given to the processing of criminal cases involving local police resources. "With and without" analysis was employed to determine the extent to which law enforcement resources (devoted to court-related activities) increased as a result of reorganization (3). Policemen spent more time traveling to and waiting in court. Travel time increases were due primarily to the greater driving distances required by the centralized court location. Increases in court waiting time were due to court congestion.

Increases in court utilization costs to rural residents in Jackson County during 1972 are shown in the table. This table includes annual law enforcement budget increases paid by local government units resulting from greater distances driven to court, more time waiting in court, and foregone annual police earnings reflecting the opportunity cost of the policeman's time in court while off duty.

Increased time costs were computed by subtracting the $1.50/hour fee paid to the off duty officer by the court from his regular or overtime hourly wage. Increased travel costs were computed by subtracting the mileage to and from decentralized courts prior to 1969 from the mileage to and from centralized courts times the total number of trips while the officer was on duty in 1972. This net increased mileage, determined by with and without analysis, was multiplied by $.10/mile (the mileage fee paid by the local unit).

The analysis assumes that the number of law enforcement officer trips made to court was not affected by the reorganization and that increased trips to court resulted from increased population and criminal activity. The impact of court centralization on law enforcement budgets can be seen by comparing increased costs to police salaries. These increased costs of approximately $20,000 annually, represent a 13-percent increase in 1968 prereform police salary budgets for all rural Jackson County governments.

A statewide study of Michigan State Police waiting and travel time in court-related activities was undertaken by legislative order, shortly after the study's results were made public (5). While with and without comparative measures of State police waiting time were not analyzed, the legislative study findings do show some of the costs incurred by taxpayers in support of State police utilizing centralized courts.

The two types of State police utilization costs identified and measured for the 1974-75 fiscal year included time spent traveling to and from court and time spent waiting for court activities. A measure of absolute waiting and travel time does not account for differences in the amount of State police business heard by each court, as Michigan State police posts were not uniformly distributed across the county. To control these problems, one can show court waiting and traveling time as a ratio of productive (giving testimony, signing complaints, picking up dispositions, and the like) to unproductive (waiting and traveling) court activities.

Michigan State police, when averaged by county, spent 52 minutes waiting and 42 minutes traveling for each productive hour spent in district court. State patrolmen, as a whole, spent 29,210 hours waiting in court, 19,849 hours of which were classified as overtime; and 28,296 hours traveling to and from court, 11,382 hours of which was classified as overtime. The magnitude of these costs are cause for public concern, even though the net increases in State police utilization costs could not be computed because data on these costs prior to centralizaton (or more precisely, "without" centralization) were not available.

No attempt was made by either of these studies to document benefits or cost savings from centralization. Such cost savings were not the source of local resident dissatisfaction with the centralized courts. Local residents were skeptical of those who promised greater cost savings from centralization because they feared these centralized courts would be less accessible to rural residents. From the rural residents' perspective, both production and delivery or utilization costs must be considered.

Savings in production costs from centralization for many rural residents were offset by increases in court utilization costs resulting from reduced accessibility. Rural residents were thought to be more concerned with the redistributive consequences

Increases in Jackson County Michigan's court utilization costs, resulting from 1969 reorganization, 1972 1/

Township	Population 1970	Increased annual costs, law enforcement		Foregone annual earnings by law enforcement officials	Annual police salary budget, 1968	Increased costs as percentage of policy salary budget
		Time	Travel			
	Number	- - - - - - - - - - -	- - Dollars - -	- - - - - - - - - - -		Percent
Blackman	16,997	2,897	2/0	5,959	12,920	68
Leoni	13,953	1,335	48	2,046	32,400	11
Summit	21,754	1,056	65	1,711	64,500	4
All townships and villages	83,491	7,534	1,428	11,010	154,593	13

1/ Not shown are travel time costs borne at the county level, which total $6,647.
2/ Because of the township's proximity to the 12th District Court, the reorganization had no substantial effect on travel expenses.

Source: Josef M. Broder and A. Allan Schmid, "The Impact of Michigan's 1969 Lower Court Reorganization on Rural Citizens," Michigan Farm Economics. East Lansing, Mich.: Dept. Agr. Econ., Mich. State Univ., Oct. 1973.

within and across local communites than with net gains or losses to the State treasury.

Rules for Other Community Services

For those State and local officials contemplating structural changes in community service delivery systems, the number and location of delivery units makes a difference. Total costs of service and quantity of service to rural residents are functions of service accessibility, regardless of whether the discussion centers around courts, schools, bus stops, or dam sites. Utilization costs and their effect on agency performance and user behavior cannot be ignored in choosing alternative community service delivery units.

Community service scarcity and settlement patterns impose unequal utilization costs for different groups. Differences in community service utilization costs raise the question of whether standards used to evaluate public service delivery system for urban areas are valid for evaluating rural community service delivery systems. Public debate during the Michigan local court reorganization illustrates this issue. Reform advocates argued that court centralization and consolidation would save the general taxpayer money because a single court requires fewer operating expenditures than several scattered, overlapping, uncoordinated small courts. Court reformers concluded that greater efficiency could be achieved through a scheme whereby people transport themselves to court, rather than by maintaining many small courts in local areas. 3/

Where efficiency calculations are limited to internal operations, an expansion in size of operation will, under certain conditions, lead to a reduction in average costs. 4/ From a distribution or marketing perspective, a different set of efficiency calculations results when both production and delivery or utilization costs are included. For Michigan's densely populated urban areas, the reorganized courts had little impact on efficiency, regardless of the costs included in the calculations.

The same production efficiency criteria when applied to rural areas, however, are misleading in predicting cost of bringing services to people versus bringing people to services. Cost savings due to expected economies of scale in production may be offset by increased utilization costs for Jackson County's rural residents. These findings are consistent with those found in a study by Hawkins in which few economies of scale were found to exist for most governmental services.

Those choosing alternative community service delivery systems should not only look at the magnitude of service utilization costs but also their distribution among various groups. Where the cost of transporting people and/or services is financed by a third party (as with many medical, educational, or nutritional services), one would expect service participation or utilization to be comparable across alternative delivery schemes.

Efficiency calculations for the above situation are relatively simple. When community service participants bear the utilization costs, comparable levels of utilization or participation may not exist under alternative delivery schemes. Court reformers, in boasting of average production cost savings for centralized court

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3/ The reader will note that the concept of efficiency used by court reformers does not meet the assumptions behind the economists' use of the term, that is, that efficiency is an input-output relationship and that service content does not change with size of operation.

4/ According to Hawkins, economies of scale are usually realized in those services that are capital intensive but are negligible in services that are labor intensive (4).

services, failed to realize that the extent to which local residents utilize a particular community service depends not so much on the average cost of providing that service but rather on the marginal costs incurred by citizens using the service. Average costs for many community services are typically financed by taxes and have little bearing on the marginal costs associated with using that service.

Scattered evidence of police and citizen reluctance to pursue litigation was found in the Jackson County study. Police officers admitted that arrests for certain types of offenses were not worth the costs of travel time to and waiting time in the centralized courts. Thus, local court centralization and consolidation served to increase the marginal cost of going to court and decreased local supply of court services for many of Michigan's rural residents.

So that comparable levels of court and police services were assured, local units had to increase taxes or reduce the level of other community services. Communities with limited finances, unable to pay increased law enforcement costs, were forced to live with crimes and civil disputes which were too costly to resolve.

The Michigan local court experience suggests that the degree of difficulty in maintaining comparable service content across delivery systems depends upon standards of service content which are set by selected groups. The requirement that all judges be attorneys raised the price of judges and resulted in fewer judges per capita. Many urban courts, at the time of the reorganization, were already staffed with professional judges and those that were not did not experience a reduction in judges per capita or the financial plight of the sparsely settled rural areas.

Because court professionalization and standardization ignored rural people's willingness and ability to pay, it is unrealistic to assume that professionalized courts, which are economically feasible when people reside in or near a central location, can be delivered with the same level of accessibility in rural areas. Where the burden of community service financing falls on local residents, standards of service content greatly affect the number and location of service delivery units in the rural areas. Community service standards, which are costly to maintain relative to ability to pay, mean that those services will tend to be less accessible with respect to time and location.

CONCLUSIONS

Production economies of scale, while never systematically documented, became only one argument for court consolidation and centralization. This author suspects that the main thrust behind court reform is a desire to professionalize local courts and to deliver a standardized service to all residents, regardless of location or differences in effective demand. Attempts to professionalize and standardize local courts in Michigan raises the question of whether the content of community services is comparable across alternative service delivery schemes, that is, can rural residents expect the same service regardless of whether the service is brought to them or they bring themselves to the service?

Centralized courts studied in Michigan caused court services to be less accessible in time and location and required additional local law enforcement resources. As these court utilization costs fall primarily on rural residents, the quantity demanded for such services was reduced because of an increase in the price or marginal cost of going to court.

Those local and regional planners choosing community service delivery systems should remember that the number and location of service delivery units make a difference in the cost and quantity of services to rural areas. Rural resident participation or use of community services depend more on marginal costs, not the average cost of producing the service. When minimum standards for service content are set too high, local residents lose accessibility to these services.

When comparing alternative service delivery schemes, planners must weigh diseconomies of scale in service distribution against economies of scale in production. Effective demand for service quantity and content in rural areas tends to differ from that in urban areas. Similarly, service delivery schemes designed for urban areas create high service utilization costs for rural and sparsely settled areas. Advancements in service delivery technology and changes in transportation costs require periodically assessing the advantages of alternative service delivery systems.

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CONDITIONS AND FINANCING OF RURAL ROADS AND BRIDGES IN ILLINOIS

By Norman Walzer and Ralph Stablein 1/

INTRODUCTION

Local governmental officials maintain that the financial resources available for providing local public services are no longer adequate. This condition has been caused by at least four factors. First, the general rise in the standard of living of most Americans has caused them to demand better services which cost more to provide. Second, the inflation experienced during the early seventies cut significantly into the financial resources available for providing services. Third, revenue instruments available to local governments are relatively unresponsive to income increases, which causes resource needs to outstrip the ability to finance them. Fourth, tax increases and inflation have caused citizens to reject proposed governmental expenditures.

Illinois' road districts have been particularly affected by rising costs because some of the greatest price increases have been for petroleum-based products used extensively in road construction and maintenance. Locally maintained bridges which were constructed in the thirties are worn out and need major repair or replacement. The increased weight of farm machinery and equipment has accelerated road deterioration and many bridges are too narrow to accommodate larger sized machinery.

THE ILLINOIS SITUATION

The vast majority of low-volume rural roads in Illinois are maintained by road districts. There were 88,405 miles of roads under the control of townships and towns in Illinois in 1974; these roads represented 82.5 percent of the locally controlled roads (5). 2/ The township-controlled roads comprised 71.6 percent of the total road mileage under local control. Technically, Illinois' road districts are separate from townships and are charged with maintaining the roads from an independent budget. However, their budgets must be approved by the township's board of trustees.

Funding Arrangements

One major funding source of road and bridge maintenance is the locally imposed property tax on real estate. This property tax represented 42 percent of the road and bridge funds's total revenue in fiscal year 1974. A State tax of 7.5 cents per gallon on gasoline is shared with municipalities, counties, and road districts. The road district allotment is based on the district's road mileage, with the funds held by the county superintendent of highways. The road commissioner is reimbursed for approved

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2/ Underscored numbers in parentheses refer to items in Literature Cited at the end of this article.

expenditures and projects. Illinois, in 1974, ranked fourth in State expenditures and grants in aid for local roads and streets to counties and townships; the State's expenditure in this area totaled $152,883,000. Only California, Michigan, and Ohio reported larger amounts.

Based on data from Entitlement Period 4 (July 1, 1973 to June 30, 1974), it appears that townships allocated substantial amounts of their general revenue-sharing funds to road maintenance (7). The average expenditure reported for public transportation by all Illinois townships was $7.13 and $8.99 per capita for operating-maintenance and capital expenditures, respectively. The comparable figures for the 10-county study area in western Illinois were $10.09 and $11.45 per capita. These amounts, by far the largest portion of township expenditures, were reported by the largest number of townships.

Road Surface

Illinois' local roads compare favorably with the Nation's in terms of local road surfaces. Forty-eight percent of the State's rural road mileage was either soil surface or slag, gravel, or stone, the same figure as for the United States as a whole. Five percent of the Illinois roads had a concrete or bituminous wearing surface of less than 1 inch, while nationwide, approximately 2.4 percent had such a surface. Illinois had a slightly higher percentage in the bituminous category, but does not differ substantially from the national average.

The Illinois Department of Transportation (IDOT), in the early seventies, initiated a road and bridge inventory to monitor the State's continuing transportation needs. The roads are rated on a 9-point scale; a 0 or 1 designates roads with failures to the extent that operation of traffic is severely affected, while a 9 is assigned to roads in a new or perfect condition (see appendix A). A profile of the surface type and condition by traffic count of the western Illinois road districts is presented in table 1.

Surface-type condition information is limited to surfaces and does not consider foundation, right-of-way width, drainage, or other essential characteristics. The vast majority of the low-volume roads are gravel or stone surface. The relative importance of this surface type declines as the average daily traffic (ADT) increases.3/ For example, for roads with fewer than 50 vehicles per day, 68.9 percent had a loose aggregate surface. This surface represented 50 percent of the road mileage with an ADT of over 401. The State's more heavily travelled township roads had a seal coat surface.

According to the IDOT rating system, roads rated below 6 have limited failures, are barely adequate, and require higher than normal maintenance to prevent continued deterioration. 4/ Thus, one measure of road deterioration is the percentage of road mileage rated at 5 or below.

More than one-half of the gravel or stone roads and more than two-thirds of those with a seal coat surface within the 0 to 50 ADT category were rated barely adequate or below. The comparable percentages decreased as traffic volume increased, but the data suggest that almost half the roads in the 51 to 150 ADT group will require higher than

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3/ ADT represents the average number of vehicles that travel over a section of road or street during 24 consecutive hours.

4/ The roads are rated in terms of right-of-way width, drainage structures, foundation, and condition of surface. Because of space limitations, only the surface condition was reported here. For more information see (4).

Table 1--Surface type and condition by traffic count of western Illinois road districts

Average daily traffic and surface type	Total miles	Distribution by surface condition						
		0 to 2	3 to 5	6 to 8	9	No data	Total	Percent rated 5 or less
	Number	Percent						
0 to 50 ADT:								
Earth or oiled earth	834.98	62.6	35.2	1.3	0.1	0.8	100.0	97.8
Gravel or stone	3,179.73	2.9	50.0	45.2	.3	1.6	100.0	52.9
Seal coat	497.91	.8	66.7	31.5	1.0	--	100.0	67.5
Low-type bituminous	3.47	--	30.3	57.0	12.7	--	100.0	30.3
Paved	.73	10.9	37.0	26.0	21.9	4.1	100.0	58.8
51 to 150 ADT:								
Earth or oiled earth	97.93	33.9	35.0	29.8	--	1.3	100.0	68.9
Gravel or stone	596.31	--	52.8	46.5	.1	.6	100.0	52.8
Seal coat	351.35	.3	45.6	53.5	.6	--	100.0	45.9
Low-type bituminous	2.43	--	--	100.0	--	--	100.0	--
Paved	.15	--	73.4	26.6	--	--	100.0	73.4
151 to 400 ADT:								
Earth or oiled earth	5.03	18.5	.8	66.2	--	14.5	100.0	19.3
Gravel or stone	59.31	--	43.8	41.4	2.6	7.3	100.0	48.8
Seal coat	83.23	--	32.4	61.4	--	6.2	100.0	32.4
Low-type bituminous	1.79	--	.6	100.0	--	--	100.0	--
Paved	.84	--	97.6	2.4	--	--	100.0	97.6
401 and above ADT:								
Earth or oiled earth	1.08	100.0	--	--	--	--	100.0	100.0
Gravel or stone	12.73	--	3.0	97.0	--	--	100.0	3.0
Seal coat	10.00	--	19.5	75.5	--	5.0	100.0	19.5
Low-type bituminous	.28	--	3.6	--	96.4	--	100.0	3.6
High-type bituminous	1.03	--	--	45.6	54.4	--	100.0	--
Paved	.31	--	83.9	16.1	--	--	100.0	83.9
Total	5,740.62	11.4	48.5	38.4	.4	1.3	100.0	59.5

-- = Less than 0.05.

Source: Illinois Department of Transportation (unpublished data).

normal maintenance. In the 151 to 400 ADT group, almost half the gravel or stone surfaces and approximately one-third of those with a seal coat are in this category.

Well-travelled roads, on the average, are in much better condition, although the number of miles involved is insignificant. Only 25.43 miles, of a total 5,740,62 miles, had an average daily traffic volume greater than 400 vehicles within the 186 western Illinois townships.

Considerable variation exists among townships regarding road conditions because of differences in financial resources available to the townships, variations in management practices and objectives followed by road commissioners, and differences in the townships' needs for roads. It is difficult to estimate the cost of bringing the roads up to adequate standards because, on economic grounds, the condition in which a road should be maintained varies with the amount of travel, which, in turn, varies with the condition in which the road is maintained.

Deficiencies in Local Bridges

The generally poor condition of local bridges is a national issue, and conditions in Illinois are similar to those in most other States (1). Approximately a third of the bridges, statewide, have been rated according to their condition as part of the continuing IDOT-maintained data bank.

The bridges are rated from 0 to 9; 0 indicates that immediate replacement is necessary, while a 9 indicates a condition superior to present desirable criteria. 5/ A rating of 4 means the condition meets minimum tolerable limits. Thus, bridges rated 3 or below are obviously inadequate, and those rated 5 and above are reasonably safe (see appendix 1).

Bridge conditions should be examined by size or length if the costs of improving the quality are to be estimated. Construction costs are most meaningful when presented on a per square foot or per unit basis. Table 2 shows bridge conditions for the area studied. The condition information is provided in four classifications: a rating of 0 to 3 indicates less than minimum or tolerable limits; a rating of 4, minimum tolerable limits, to be left in place as is; a rating of 5 to 8, above minimum conditions; and a rating of 9, excellent condition.

Approximately 25 percent of the bridges in the study area have been rated. About one-half of the bridges in western Illinois (50.4 percent) have been rated at minimum tolerable condition or below based on table 2 information. This is a conservative estimate of the seriousness of the bridge problem because a rating of 6 indicates that a bridge meets the present minimum standards and a rating of 8 indicates that a bridge meets present desirable standards. If a rating of 6 is used, 59.6 percent of the bridges fail to meet present minimum criteria and 22.4 percent exceed these criteria. Regardless of the measure used, many of the bridges are in serious disrepair. Most of them were built in the thirties or earlier and many require complete replacement. Table 2's figures do not account for the fact that some of the safer bridges are too narrow to accommodate today's farm machinery.

5/ The bridges are rated on many characteristics and a "composite" measure is not readily available. For present purposes, the condition of the bridge structure is being used as a measure of bridge condition.

Table 2--Condition rating by length of township bridges in 10 western Illinois counties

Structure length (feet)	Percentage with condition rating					Number rated	Total structures
	0	1 to 3	4	5 to 8	9		
	Percent					Number	
21 to 29	1.3	18.8	20.0	59.9	--	80	310
30 to 39	--	18.5	26.1	55.4	--	92	352
40 to 49	7.3	26.8	26.8	36.7	2.4	41	171
50 to 59	4.2	41.6	25.0	25.0	4.2	24	115
60 to 69	--	37.5	25.0	37.5	--	24	94
70 and over	1.1	30.7	20.5	37.5	10.2	88	304
Average/total	1.7	25.5	23.2	46.4	3.2	349	1,346

-- = Less than 0.05.

Source: Illinois Department of Transportation (unpublished data).

ESTIMATED COST OF UPGRADING TOWNSHIP ROADS

An attempt was made to estimate the cost per mile of bringing western Illinois bridges to acceptable standards (4). In arriving at these costs, it was necessary to establish acceptable standards for roads, given traffic patterns and soil conditions for the locale. Two approaches were available. First, IDOT has very general guidelines for width, drainage, or surface condition for road district roads with less than 150 ADT and from 151 to 400 ADT. The cost of rebuilding roads to meet these standards would provide a suitable cost measure, but obtaining the detailed information on the purchase price of materials, transportation cost, and wage rates from each highway commissioner was not practical. Given the needs and traffic patterns, these standards may be higher than necessary for a portion of the roads in the study.

The alternative approach, the one which was followed, assembled local policymakers, such as county highway superintendents, who in Illinois have extensive engineering backgrounds and are familiar with the needs and conditions in the area, and elicited their appraisal of suitable road conditions.

County superintendents were requested to indicate the acceptable standards for each of the area's five major road characteristics: right-of-way width, drainage structure, grade standards, surfacing and miscellaneous utility, and erosion control. The standards varied by traffic volume category (ADT). Within each category the roads were grouped as high, average, and low cost depending on terrain and soil conditions. The per mile cost of meeting the agreed-upon standards within each category was calculated based on the superintendents' knowledge of material costs and area conditions.

The minimum standards agreed upon by the highway superintendents are shown in table 3. These standards are not necessarily those desired by the highway superintendents or road commissioners; rather, they represent the road characteristics that would provide adequate service for the area. Standards were established for comparing right-of-way width, drainage conditions, and surface type to existing area roads.

The general requirements for minimum design policies for district roads, as recommended by IDOT for those with less than 150 ADT, include a lose aggregate surface or bituminous treated earth of 16 feet with a right of way of at least 20 feet. Roads with a volume of 150 to 250 ADT should have a design speed of 40 mph and a loose aggregate surface of 20 feet. Thus, the standards shown in table 3 meet bare-minimum recommendations of the State's transportation department.

The resulting cost estimates will necessarily be conservative, because these standards are less than what would be desired if cost considerations were unimportant. Certainly, the higher the standards, the greater the per mile cost. However, given the engineering backgrounds of the county superintendents and their familiarity with the township roads, one would expect the estimates to apply to the roads providing reasonably safe passage in most weather conditions.

The per mile cost of western Illinois' roads meeting these accepted standards, as shown in table 4, ranges from $16,500 to $74,000, depending upon the volume category and terrain characteristics. The major cost variations within each volume category occur from differences in the amount of grading that must be done to prepare the foundation and the work needed to provide adequate drainage. Also, there were substantial differences among the volume categories in the need for right-of-way purchases. These figures must be viewed as approximations, as detailed information on current road conditions, terrain, and drainage was not available for each mile of road. More detailed information on the major cost components is provided in appendix table 1.

Table 3--Minimum acceptable standards for township roads in 10 western Illinois counties

Volume	Standard
0 to 50 ADT:	
Right-of-way width	16-foot roadbed
Drainage (culverts and structures less than 20 feet)	1- to 5-year frequency, low water crossing
Surface	Shortest way out, all weather, loose surface
51 to 150 ADT:	
Right-of-way width	20-foot roadbed
Drainage (culverts and structures less than 20 feet)	1- to 5-year frequency, low water crossing
Surface	Dust-free surface (oil or chemical), 4 inches of material
151 to 400 ADT:	
Right-of-way width	24-foot roadbed
Drainage	10-year frequency, low water crossing
Surface	6- to 8-inch base, 20-foot width, base with less than 1 inch of material
401 and over ADT:	
Right-of-way width	28-foot roadbed
Drainage	Over 15-year frequency, low water crossing
Surface	10-inch base, 24-foot width, base with less than 1 inch of material

Note: ADT means average daily traffic.

The total cost of upgrading township-maintained roads by traffic volume category is shown in table 4. The cost is based on the distribution of road mileage among high, average, and low-cost terrains. The estimated total cost of upgrading the township's roads was $217,397,975 in 1976 dollars.

This cost figure becomes more meaningful when placed in the perspective of population and road mileage. If the cost of upgrading these roads is distributed among all residents in the 186 townships, the per capita cost would be $731. If rural residents (with residents in communities of 2,500 and over removed from the calculations) are used as the base, the cost increases to $1,543 per person. However, this cost would still be spread over residents in communities with less than 2,500 population. Dividing the total cost by miles of township-maintained roads yields an average per mile cost per person of $27,105.

Again, engineering standards used to calculate these costs are not those necessarily desired by local officials, but rather those considered adequate for providing serviceable and reasonably safe travel under most weather conditions. Higher road standards increase the cost of upgrading roads, which makes it difficult for planners to determine the approximate road quality when faced with limited financial resources.

Table 4--Estimated cost of improving township roads

Traffic count	Per mile cost	Total cost
	Dollars	
0 to 50 ADT:		
High	34,500	52,408,260
Average	24,000	60,769,680
Low	16,500	16,711,035
51 to 150 ADT:		
High	37,000	23,007,340
Average	26,500	32,951,955
Low	19,000	11,814,580
151 to 400 ADT:		
High	60,000	4,548,600
Average	48,500	9,195,600
Low	39,000	443,430
401 ADT and over:		
High	74,000	776,260
Average	62,500	2,545,765
Low	53,000	2,225,470
Total	--	217,397,975

-- = Not applicable.
Note: ADT means average daily traffic.

ESTIMATED COST OF UPGRADING BRIDGES

The usefulness of rural roads is limited by the adequacy of the bridges serving them. County highway superintendents were asked to develop cost estimates for reconstructing or replacing bridges to meet the region's needs. They were asked, in particular, to consider the possibility that some might not be needed and that culverts or other structures might be used as replacements for others. The superintendents were instructed to place special emphasis on travel needs, current condition of the structures, and the financial situation of the area's townships. Cost figures for bridges, while not based on ideal standards, represent estimates for conditions that will accommodate travel needs in the region and assure safe passage in most weather conditions.

Highway superintendents estimated that at least 5 percent of the area's bridges could be eliminated without imposing serious hardships on the residents. No improvements were necessary for 15 percent, which is consistent with the earlier finding that 22.3 percent of the township bridges exceed the present minimum criteria. Twenty percent of the bridges would require major repair work, at an average cost of nearly $70,000 per bridge. The remaining 60 percent would require approximately $35,000 per unit for upgrading or replacement.

Table 5 shows the expenditures needed to upgrade local bridges. The region has 1,346 bridges; 1,077 need repair or replacement--a total cost of $47,110,000, or $43,742 per bridge. If one extrapolates these figures statewide, the estimated cost becomes nearly $400 million. These costs are understated because of the standards imposed. However, at present tax rates, there simply may not be enough money to provide high-quality roads and bridges in sparsely travelled areas. Yet, most would agree that rural residents are entitled to medical facilities and other basic services that require access to rural homesteads.

Cost of Not Upgrading Roads

The data in the following analysis were obtained from a Highway Research Board (HRB) national study. The data were used to obtain rough estimates of differentials in user costs based on differences in road surfaces (3). Detailed information on cost differentials by surface type is based on specific assumptions about incline, speed travelled, and weather conditions. Poorer road cost is measured by the additional expenditures for vehicle operation mandated by a lower road quality. If road conditions require detours or slower speeds, then the value of the driver's additional time spent in transit is included.

Higher Operating Costs

Vehicle operating or running costs consist of fuel consumption, oil consumption, tire wear, maintenance, depreciation, and accident cost. HRB permits development of cost estimates for fuel consumption, oil consumption, and tire wear. These data were based on field experimental measurements using test vehicles on roads under varied design conditions and road surfaces.

Test vehicle results were summarized based on an average figure for a composite vehicle of each type (passenger car, pickup truck, and 2-axle 6-tire truck). The composite passenger car estimates were computed with the following vehicle distribution: large cars, 20 percent; standard-sized cars, 65 percent; compact cars, 10 percent; and small cars, 5 percent. The composite pickup truck represents a weight distribution of 85 percent at 4,800 pounds and 15 percent at 5,800 pounds. The composite 2-axle 6-tire truck represents 50 percent at 8,000 pounds and 50 percent at 16,000 pounds (3).

Conditions under which the following data were developed included a level road with free-flowing traffic and good weather conditions, with test vehicles well tuned and in good operating condition. Thus, these estimates are based on ideal conditions. Actual operating costs may be higher due to road curvature, road grade, and traffic and weather conditions.

Current input prices were multiplied by the technical rates of consumption to arrive at per mile costs in each category by vehicle type. Since gasoline and tire usage vary with speed, the costs of several speeds of operation are reported. The weighted average cost per mile for a composite rural road vehicle was calculated based on a traffic distribution of 77-percent passenger cars and 23-percent trucks (6). The trucks were assumed to be 50-percent pickup and 50-percent 2-axle 6-tire vehicles (table 6).

Note that vehicle operating costs are substantially higher on gravel roads. Costs attributable to added fuel, oil, and tire consumption range from 32.5 percent to 104.3 percent higher on the gravel surface. The main element in these cost figures is fuel consumption. Gasoline consumption on a gravel road can be as much as 70 percent higher than on an asphalt road (at 50 miles per hour). These estimates are for good quality surfaces. A badly broken and patched asphalt surface would mean up to 50 percent greater fuel consumption over the good asphalt surface. A poor-quality surface would also mean higher tire wear, but data to quantify this cost were not

Table 5--Cost of upgrading township bridges

Action proposed	Bridges	Estimated cost
	Number	Dollars 1/
Eliminated	67	0
No work needed	202	0
Major renovation ($70,000)	269	18,830,000
Moderate upgrading ($35,000)	808	28,280,000
Total	1,346	47,110,000
Average cost per bridge to be repaired or replaced	--	43,742

-- = Not applicable.
1/ 1976 prices.

Table 6--Fuel, oil, and tire running cost

Speed and road surface	Automobiles 1/	Pickup trucks 2/	Two-axle, six-tire trucks 3/	Average 4/
	Cents per mile			
20 MPH:				
Asphalt	3.62	3.48	3.97	3.64
Gravel	5.37	5.27	5.26	5.35
30 MPH:				
Asphalt	3.36	3.61	4.47	3.52
Gravel	5.33	5.50	6.62	5.50
40 MPH:				
Asphalt	3.57	4.07	5.42	3.84
Gravel	6.39	6.29	8.67	6.64
50 MPH:				
Asphalt	3.99	4.85	6.61	4.39
Gravel	8.15	7.59	11.25	8.44

Note: MPH means miles per hour.

1/ Composite passenger car: large car, 20 percent; standard-size car, 65 percent; compact car, 10 percent; and small car, 5 percent.
2/ Composite pickup truck: 4,800 pounds, 85 percent; 5,800 pounds, 15 percent;
3/ Composite two-axle, six-tire truck: 8,000 pounds, 50 percent; 16,000 pounds, 50 percent.
4/ Composite rural vehicle: passenger car, 77 percent; pickup truck, 11.5 percent; and two-axle, six-tire truck, 11.5 percent.

Source: Calculated from National Cooperative Highway Research Program Report 111 and Consumer Price Index.

available. Detailed fuel, oil, and tire cost estimates by vehicle type and road surface are provided in appendix table 2.

The estimates in table 6 include three of the six categories of vehicle running cost. These are the items for which useful data are available by road surface. The National Cooperative Highway Research Program reports average maintenance expenses of 1.15 cents per mile and 1.42 cents per mile for cars and pickup trucks, respectively (3). Maintenance for vehicles travelling on gravel or poor surfaces would certainly be higher than these averages. Maintenance costs on gravel roads have been estimated to be 100 percent higher than on high-type surfaces (2). If so, gravel roads add at least a cent per mile to the operating cost of a vehicle.

Accident costs by surface type are not readily available and, therefore, have not been included. Gravel surfaces would be expected to increase depreciation cost per mile, but specific data to support this contention could not be found. If road conditions are such that vehicles are required to stop or reduce speed (that is, to avoid potholes), operating costs increase even more. Other nonrunning cost factors, particularly safety, should be recognized.

The available data, though not complete, clearly establish that lower quality road surfaces result in substantially higher vehicle operating costs. For example, assume a 1-mile section of gravel road with average daily traffic of 100 vehicles. The cost of operating the composite vehicle on this road would be 8.44 cents per mile at 50 miles per hour. The cost would be 4.39 cents per mile, if the surface is asphalt. Thus, the costs on gravel are over 90 percent higher--4.05 cents per mile. Multiplying this per mile cost by the number of vehicles travelling the road yields a daily cost per mile differential of $4.05, or $1,478.25 per mile per year. This differential is based on a comparison of two road surfaces in good condition. If data were available to calculate the cost increase from deteriorated surfaces, the differential would be substantially more.

Other Economic Considerations

Higher transportation costs due to a poor-quality road system affect the production cost of agricultural commodities. Either higher prices or lower profit margins may result from inadequate roads. Rural school districts must spend more to transport students on a poor road system, which means higher taxes to provide the same level of educational quality. The added cost of mail delivery is paid by all taxpayers.

There are other benefits from improved township roads which should be included in any cost-benefit analysis. Residents in rural areas must have access to fire protection and health services. The increased interest of urban residents living in the countryside surrounding their place of employment is also likely to promote an even greater need for area access.

Bridges, rather than roads, are often a more critical safety problem. The average traveler can travel poorly maintained roads with reasonable safety. He is not, however, in a position to judge the safety of a bridge. A bridge failure can mean the loss of life or very serious injury.

General Observations

What is an effective policy for financing road and bridge improvements? Given the complexity of the issue and the high cost of rebuilding the roads and bridges, there is no obvious solution.

Recent Illinois legislation allowed road districts to increase their tax rates for road and bridge purposes to 0.66 percent (66 cents per $100 assessed valuation) by referendum. Formerly, the maximum permitted with referendum approval was 0.33 percent. The average tax rate in the 30 townships, as of 1976, was 0.216 percent (0.33 percent was the maximum). This means that on the average, road districts have some leeway to increase revenue from their own sources. The districts can levy a tax of 0.05 percent for bridges. The average road district is levied at 0.046 percent which, for all practical purposes, means that they are at their taxing limit.

The Illinois legislature in June 1976, passed a $15-million bond program to be administered by IDOT for improving bridges on county, township, and municipal highways and streets. Prime consideration was to be given to school bus routes. Each county submitted 5 priority bridges and 196 were chosen from this list for improvement.

As of July 1, 1977, $15 million would be provided annually to counties for distribution to townships that are levying the maximum (without referendum) for road and bridge purposes. Consideration in selecting the bridges is to be given to school bus needs, mail routes, transfer of agricultural products, and anticipated travel needs of the general public.

Legislation was introduced in the Illinois General Assembly in the 1977 session to create a bridge repair and rehabilitation fund from an increase in the State tax on motor fuel. Forty percent of the funds generated would be allocated to bridges on district maintained roads. The bill died in committee.

A feasible solution to the road and bridge problem will require funding from township, State, and Federal sources. During the past 6 years, the Federal Highway Administration provided almost $640 million to States, resulting in the replacement of 987 bridges (1).

Attempts to find a solution to the local road and bridge problem have caused planners to think in terms of additional funds. Another course of action, the closing of some roads and bridges, should at least be considered. Tables 4 and 5 indicate that the major cost of bringing roads to adequate standards involves roads with a very low traffic volume.

Given the high cost of repair and maintenance, it may be necessary to close some of the less frequently used roads and bridges. No one would dispute that every resident must have access to his property, but it may not be essential that all roads, regardless of how little used, be maintained at high levels. It might be possible, for example, that a road could be closed at considerable savings and the land converted to agriculture. Of course, there would have to be some method of compensating landowners for reduced property values.

Road or bridge closing will certainly encounter opposition from those affected but, faced with rising costs of bringing facilities up to adequate standards, this policy should at least be considered. If this strategy were followed, however, an effort would have to be made to provide an efficient traffic network for the rural residents affected. Thus, the selection of roads to be closed would not necessarily be made based on which were in the poorest condition or the most expensive to repair. Rather, a serious attempt would be made to identify the central nodes around which the traffic is centered and a system of roads maintained which would allow rural residents the greatest access to these points.

CONCLUSIONS

The conditions of Illinois' rural roads and bridges, especially bridges, is a serious problem--one which must be faced immediately. Improvement costs will be staggering, yet every year postponed increases the cost of the solution. An organized plan must be instituted in those townships where the bridge situation is critical, whereby the main roads needed for medical facilities and other essential services receive adequate attention, with an efficient road network also available for marketing agricultural products.

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Appendix A

ROAD RATING SCHEDULE

Rating	Road Condition
9	New or near perfect condition
8	
7	Surface adequate with normal maintenance
6	Limited failures and barely adequate, maintenance will be considerably higher than normal to prevent continued deterioration
5	
4	
3	Considerable failures and disintegration beyond practical limits of normal maintenance
2	
1	Failures to the extent that operation of traffic is severely affected
0	

BRIDGE RATING SCHEDULE

Rating	Road Condition
9	Conditions superior to present desirable criteria
8	Conditions equal to present desirable criteria
7	Conditions better than present minimum criteria
6	Condition equal to present minimum criteria
5	Condition somewhat better than minimum adequacy to tolerable being left in place as is
4	Condition meeting minimum tolerable limits to be left in place as is
3	Basically intolerable condition requiring high priority of replacement
2	Basically intolerable condition requiring high priority of replacement
1	Immediate repair necessary to put back in service
0	Immediate replacement necessary to put back in service

Source: Illinois Department of Transportation

Appendix table 1--Cost of upgrading township roads, 1976 dollars

Traffic count	Construction categories					Total
	Row width	Drainage structures	Grading	Surfacing	Miscellaneous: utility erosion control	
	Dollars per mile					
0 to 50 ADT:						
High	2,000	12,000	10,000	10,000	500	34,500
Average	0	6,000	7,500	10,000	500	24,000
Low	0	3,000	3,000	10,000	500	16,500
51 to 150 ADT:						
High	2,000	12,000	10,000	12,000	1,000	37,000
Average	0	6,000	7,500	12,000	1,000	26,500
Low	0	3,000	3,000	12,000	1,000	19,000
151 to 400 ADT:						
High	3,000	15,000	10,000	30,000	2,000	60,000
Average	2,000	7,000	7,500	30,000	2,000	48,500
Low	1,000	3,000	3,000	30,000	2,000	39,000
401 ADT and over:						
High	3,000	15,000	12,000	40,000	4,000	74,000
Average	2,000	7,000	9,500	40,000	4,000	62,500
Low	1,000	3,000	5,000	40,000	4,000	53,000

Note: ADT means average daily traffic.

Source: Barbara W. Solomon and Norman Walzer, Rural Roads in Illinois: Township Administration and Finance (Urbana: Institue of Government and Public Affairs and Illinois Agricultural Experment Station, 1977), p. 144.

*U.S. GOVERNMENT PRINTING OFFICE : 1979 0-310-945/ESCS-1

Appendix table 2--Vehicle running cost, 1976 dollars

Item	Speed and road surface							
	20 MPH		30 MPH		40 MPH		50 MPH	
	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel	Asphalt	Gravel
	Cents per mile							
Composite passenger car: 1/								
Fuel 2/	3.20	3.62	2.82	3.55	2.94	4.59	3.33	6.31
Oil 3/	.07	.40	.07	.40	.07	.40	.07	.40
Tires 4/	.35	1.35	.47	1.38	.56	1.40	.59	1.44
Total	3.62	5.37	3.36	5.33	3.57	6.39	3.99	8.15
Composite pickup truck: 5/								
Fuel 6/	3.00	3.27	3.00	3.48	3.34	4.24	4.10	5.49
Oil 3/	.06	.40	.06	.40	.06	.40	.06	.40
Tires 7/	.42	1.60	.55	1.62	.67	1.65	.69	1.70
Total	3.48	5.27	3.61	5.50	4.07	6.29	4.85	7.59
Composite two-axle, six-tire trucks: 8/								
Fuel 6/	3.72	4.76	4.22	6.12	5.17	8.17	6.36	10.75
Oil 3/	.25	.50	.25	.50	.25	.50	.25	.50
Total	3.97	5.26	4.47	6.62	5.42	8.67	6.61	11.25

Note: MPH means miles per hour.

1/ Distribution: large cars, 20 percent; standard-size cars, 65 percent; compact cars, 10 percent; small cars, 5 percent.

2/ Weighted average gasoline price Chicago standard consolidated area for Mar. 1977 = $0.64 per gallon.

3/ Replacement to remove contaminants only. Does not include oil additions for leakage and combustion. Average price of oil = $1.00 per quart.

4/ Weighted average price of four tires corrected by Mar. 1977 Consumer Price Index = $156.00.

5/ Distribution: 4,800 pounds, 50 percent; 5,800 pounds, 50 percent.

6/ Average regular gasoline price Chicago standard consolidated area for Mar. 1977 = $0.63 per gallon.

7/ Average price of four tires corrected by Mar. 1977 Consumer Price Index = $210.00.

8/ Distribution: 8,000 pounds, 50 percent; 16,000 pounds, 50 percent. Tire wear by surface data were not available for this type of vehicle.

Source: National Cooperative Highway Research Program Report 111 and Consumer Price Index.

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