Methodological Review of Analyses of Rural Transportation Impacts in Developing Countries

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Studies of rural transportation impacts have been carried out over the last 20 years, with emphasis on the methodology and underlying models of causal relationships. The historical sequence of rural impact methodologies and the research on rural mobility and migration carried out in several countries during the last 10 years are examined. Particular emphasis is placed on the Kenya Rural Access Road Program research, Southeast Asian Research for SEATAC, and the Mexico Mobility Study. Present impact methodologies focus too narrowly on agricultural effects, despite early observations of wide-ranging impacts. They also fail to predict the significant increases in nonfarm traffic and related economic benefits that are signaled by the relatively high value placed on travel time demonstrated in the behavior of many rural travelers. This value reflects the importance of nonfarm employment and the benefits of increased mobility and service accessibility, which are crucial to adequate impact evaluation. A causal model of impacts is described, which defines the relationships between access change and rural socioeconomic development, including the role of intervening variables. Conclusions are drawn concerning the types of models that appear most promising for future impact analysis.

Ways are examined in which the analysis of rural transportation impacts in developing countries have evolved over the last 20 years, with the objective of formulating a framework for impact analysis that covers the full range of expected primary and secondary effects. Although evaluators frequently acknowledge the wide range of transportation impacts in rural areas, quantitative analysis of these impacts has focused almost exclusively on direct, readily measurable economic effects. Surprisingly little attention has been paid to the measurement of multiplier effects and to the social distribution of economic costs and benefits. Current models demonstrate an imperfect understanding of the workings of the rural economy, focusing on agricultural production and often exclusively on cash cropping. Little is known of the values placed by rural people on such intangible assets as time, energy, health, security, social interaction, and spiritual intercession. As a result, economic models for predicting the effects of rural transport investments have shown little explanatory power when confronted with the actual consequences of such investments. This does not mean that economic models are inherently wrong, but it does mean that the current models are not good representations of the processes that are actually going on in rural areas of the developing world.

The economic and social consequences of transportation improvements in a rural setting are complexly intertwined. It is this intricate blend of economic and social consequences that is the object of development. Development is defined herein as a process of increasing human welfare for a given population in a region or community through increasing economic and social activities. The concept of human welfare, as it is used here, refers to an aggregate of individual utilities (including producer and consumer surplus concepts) as defined in the work by Hicks (*1*), to include the values of material and nonmaterial goods or services received by all members of the population.

Starting from this broad definition of the purpose for investing in rural transportation improvements, the objective can be satisfied by a variety of possible outcomes and combinations of outcomes with respect to particular utilities. These possibilities include an increase in food supply, cash income, access to consumption goods, access to services, security, social interaction, and increased satisfaction of other human needs and desires, such as personal mobility.

Ranganathan and Arunachalam (*2*) have summarized the results of the latest rural road research in India and pointed out that these recent studies, which have benefited from prior research, were still "not comprehensive enough to bring out tangible results." It is believed that this lack of tangible results can be attributed to the incomplete data bases used in the analyses, and to the lack of an explicit, clearly formulated model of development impact that can be systematically tested and refined as part of the international research agenda.

The absence of an explicit model leads to the testing of simple, plausible, usually bivariate relationships that do not have the appropriate structure to reflect a complex development process. Thus, these tests frequently prove inconclusive. An explicit model is also needed to establish the causal linkages that cannot be inferred from a purely statistical analysis.

Once models are developed to forecast all the impacts of accessibility change, including economic activity and mobility trip generation, it is necessary to estimate economic benefits in the second step of a two-step evaluation process. However, various approaches to benefit estimation may have to be used for different types of impacts. Producer surplus combined with consumer surplus (where price reductions are realized elsewhere in the society) may be the best measure of benefits for primary production increases, but consumer surplus, on the basis of a willingness-to-pay measure, may be the best estimate of the net utility of mobility trips to the traveler. The estimation of these benefits is a topic that demands the attention of professionals in the economic impact field.

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STUDIES OF MODELS RELATED TO RURAL TRANSPORTATION IMPACTS

Much of the theoretical work on rural transportation impacts has been carried out in the context of rural road improvements designed to facilitate motor vehicle traffic. Although there are other forms of rural transport, and most of the transportation that takes place in rural areas does not occur on roads (*3*), practically all of the public investment in rural transport has taken the form of rural road improvements. Consequently, the development of economic evaluation methodologies has also focused on the costs and benefits of rural roads designed to accommodate motorized vehicle traffic. Many of the concepts involved would also apply to other types of rural transportation improvements (i.e., bicycle paths, cart tracks, improved vehicles, or river transport improvements).

There have been many attempts to describe the impacts of rural roads in the last quarter century. An early summary is found in the work by Owen (*4*), which includes the following impacts:

- Increased agricultural production,
- Reduced costs of agricultural inputs,
- Greater health service availability,
- Greater availability of education,
- Greater transport service availability,
- Increased use of resources (fish, timber, etc.),
- Increased trade,
- Increased industrial economies of scale resulting in expansion,
- Increased spatial price stability,
- Greater facilities for communication (more post offices),
- Increased intensity of agriculture,
- Organizational change (more cooperatives),
- More information in rural areas, leading to changes in attitudes and behavior (e.g., risk taking),
- Reduction of illiteracy, and
- Greater productivity in the medium to long run.

Owen also examined the state of knowledge regarding the roles played by transport, communications, and education in the development process. He cited research in India, Turkey, South Korea, and Japan on the relation of communication to development. Owen also mentioned research in the United States, which showed that labor force productivity over the long run is explained to a significant extent (25 percent) by education levels, and a further 20 percent by the adoption of new technologies.

Owen noted that the impacts of rural roads were not uniform from one area to the next, and that the Community Development Program, which had provided all-weather roads to many villages in India, was limited in some cases because "other elements of productive farming were still absent" (*4*). He also discussed the potential role of transportation in reinforcing growth points and market towns in India, and the potential role of these towns in stemming rural-urban migration to the larger cities.

Although he examined the impacts of transport in a relatively systematic manner, Owen did not develop an explicit model of rural road impacts. He left it to the reader to synthesize the various effects he reported into a framework for impact analysis.

Early World Bank studies of rural roads applied the same user cost savings methodology commonly used to evaluate highway construction (*5*). This methodology proved adequate for the evaluation of projects designed to upgrade roads already carrying significant amounts of traffic. However, it failed to capture the dynamic effects on the rural economy of road construction in areas previously without road access, and consequently without vehicle traffic (*6*). In an attempt to formulate a methodology to evaluate the economic contribution of new roads in rural areas, Carnemark et al. (*7*) developed an approach based on the producer surplus that could be realized in areas of potentially high agricultural production. An implicit assumption of this methodology was that the cost savings resulting from road transport improvements would be fully passed on to farmers. This methodology was widely used to evaluate the first generation of World Bank-financed rural road projects.

The Carnemark methodology is based on the forecasting of benefits accruing to generated traffic, resulting from an increase in agricultural production, which in turn results from transport costs decreasing below a certain threshold. Thus, it reflects the benefits of a large expected increase in agricultural traffic. Benefits resulting from an increase in the nonagricultural share of traffic are not included in this model. For this reason, some project evaluations combined agricultural value-added benefits for farm-related traffic and user cost savings for nonagricultural traffic.

In most cases, actual existing shares of agricultural and nonagricultural traffic were not known. This sometimes led to the assumption that all traffic was agricultural (equivalent to assuming a multiplier of 1.0 for nonagricultural traffic) and that a large increase in generated traffic would therefore be realized. However, no benefits were attributed to growth in personal travel, since a zero opportunity cost was attributed to travel time by rural people. This interpretation caused such models to inaccurately predict the traffic impacts of rural transport improvements.

The model embodied in the Carnemark methodology is based on a view of the world where all goods are tradeable, all markets are transparent, all prices are market clearing prices, and all other things are equal. Given the market conditions prevailing in rural areas of most developing countries, it is not surprising that the projects where this methodology was applied gave mixed results. A measurable increase in production of cash crops and a consequent increase in human welfare could be observed in some places. In other places, marketed agricultural production did not increase significantly for a number of different reasons. In some cases, government price controls or the monopsonistic practices of private traders meant that farmers received too small a share of the benefits of road improvements to have an incentive to invest in additional production. In other cases, unforeseen macroeconomic events, such as drought or a fall in the world price for cash crops, meant that additional production failed to yield economic benefits.

Another model that dealt with the relationship between accessibility and growth in agricultural production in a more sophisticated way than the Carnemark model was developed by Liang (*8*). This study analyzed a detailed and wide-ranging data base for prewar China, which allowed the author to examine the constraints of land, labor, and capital on the

production response to transport accessibility. Liang showed that Chinese farmers responded to the change in access by shifting out of foodgrains for local consumption and into the production of industrial and high value nonfood export crops, resulting in an increase in net farm income. This shift also generated increased demand for food crops produced in areas with less accessibility change. Liang used a Cobb-Douglas production function to estimate the relationship between total farm output and six types of inputs (labor, land, cropping intensity, irrigation, fertilizer, and farm assets), as follows:

$$\ln Y^* = \ln k + \sum a_i \ln X_i \quad (1)$$

where

Y^* = expected farm output,
k = calibration constant,
a_i = calibration constant for factor X_i, and
X_i = factor of production.

The factors of production were

X_1 = labor,
X_2 = cultivated land,
X_3 = intensity of cultivation,
X_4 = irrigated land,
X_5 = nonirrigated land,
X_6 = fertilizer applied, and
X_7 = value of farm buildings.

This function enabled Liang (*8*) to trace specific linkages between accessibility change and changes in farm inputs and to associate these changes with specific elasticities for each factor, reflecting the constraints on that factor in the rural economy. For example, Liang (*8*) noted that in the land-constrained rural economy of China, cropping intensity showed a more elastic response to access change than land itself (extension of land under crops). This study is a good example of the use of simple but powerful econometric models to evaluate transportation impacts on the rural economy.

Despite such responses as that described by Liang (*8*) for China, rural roads frequently failed to generate increased agricultural production, but often showed significant traffic increases attributable to transport of nonagricultural commodities (e.g., fuel, firewood, and beverages) and rapid growth in personal mobility. Consequently, rural communities continued to clamor for access improvements, and planners and politicians continued to invest in them because of a widespread view that rural roads were a necessary precondition for programs to improve human welfare in rural areas. Thus, second-generation rural road programs were often undertaken in the context of integrated rural development projects, as part of a package of services that were designed to meet basic human needs and generate increased production for local consumption. Roads programs were often the most successfully executed components of such projects. It was the success of the road components of the Special Rural Development Program in Kenya, for example, that led the Government of Kenya to initiate its Rural Access Roads Program using a multicriteria approach to road selection (*9*). The multicriteria approach to rural road selection was devised as a way of approximating the results that would be obtained by a fully quantified analysis of both tangible and intangible costs and benefits. The ranking and weighting procedures involved in the application of multicriteria analysis incorporate value judgments that can be interpreted as proxies for a more precise measurement of willingness-to-pay for certain kinds of consequences. While such approaches can only approximate the measurement of the utility associated with a potential road improvement, they considerably expand the predictive value of evaluation models at a relatively low cost for additional data collection. These approaches also provide a useful mechanism for involving local groups in rural road decision making. Many governments and donors have adopted multicriteria approaches as the most efficient means for selecting rural road improvements. The World Bank accepts the use of a multicriteria approach to establish a list of candidate roads, but insists on a full economic analysis in support of the final selection (*10*).

Recently, however, the World Bank has shown renewed interest in the role of rural infrastructure, especially in relation to longer term agricultural development in Africa (*11*). The premise of this research is that transportation facilitates market integration through improving the flow of information as well as goods and services. Under favorable macroeconomic conditions, it is believed that public investments in rural transportation improvements can have a high payoff in stimulating economic growth. The initial results of this research indicate that these benefits are not realized when there is inadequate road maintenance (*12*).

In the early 1980s, evaluations of eight rural road projects were conducted, primarily intended to increase agricultural production (*13*). A comparative study of the results showed that new road construction had more of an effect on agricultural production than did road upgrading. The studies also showed that roads led to the proliferation of small shops and the expansion of rural markets. Roads improved access to health and education services but had relatively little impact on the expansion of such services. Interviews with beneficiaries indicated that rural people valued roads primarily for the access they provide to medical services, followed by travel to jobs, schools, recreational and social activities, and access to job opportunities. Increased agricultural incomes were less often perceived as a benefit.

In Kenya, for example, it was found that the incomes of female-headed households in areas served by rural access roads improvements increased more sharply than the incomes of male-headed households (*14*). This anomaly was attributable to a sharp increase in nonfarm income remitted by absent males whose access to nonfarm employment opportunities was facilitated by the new roads. Production of cash crops (produced by men) in the road-influenced areas actually decreased, while production and sales of food crops, livestock, poultry, and dairy products (mainly produced by women) increased, and on-farm consumption of food crops declined in favor of increased consumption of purchased food. Clearly, the main effect of the roads was to further incorporate rural households into the cash economy, largely by facilitating mostly male participation in the nonfarm sector.

A World Bank-financed survey of the impacts of rural road improvements in Bihar State, India, showed a shift over time toward employment in nonfarm occupations in the areas with improved roads, compared to control areas, which showed

an increase in agricultural employment (*15*). Few people commuted to work outside the village, but those who did commuted over a longer distance (20 km or more) in areas with improved roads, while the commuting distance was limited to 10 to 14 km in control areas. Similarly, persons living and working away from home were likely to be living at a greater distance from the village when the village was served by an improved road.

The survey also showed that more than half of all household trips were made by marginal farmers, students, and landless laborers. Only 10 percent of the traffic on the improved roads was accounted for by motor vehicles (including tractors, scooters, and motorcycles), 60 percent by nonmotorized vehicles (oxcarts and bicycles), and 30 percent by pedestrian movements. However, the frequency of bus service doubled over 2 years on the improved roads, and the volume of passenger traffic quadrupled over the same period. Passenger travel was primarily related to social purposes, followed by work-related trips, marketing, and service utilization. Use of social (health and education) and administrative services showed a greater response to road improvements than use of economic services (banks, veterinary centers, and cooperatives).

A model of another important subsystem of the rural impact process was developed to measure the multiplier effects of agricultural development (*16*). The major contribution of this model to the understanding of the impact of rural roads on rural development is its emphasis on the relative importance of nonfarm income and activities in the incremental changes taking place in the rural economy. A second significant finding is that consumption, rather than production, linkages account for more than half of the agricultural multiplier effect on the rural economy. This result implies that other nonagricultural activities contribute a significant share (21 to 45 percent, depending on the country) of the total growth in economic activity in rural areas.

A better understanding of the importance of nonfarm activities in the rural economy would also highlight the role of rural centers, which are the location of much of the nonfarm activity (*16*). These rural centers serve two distinct functions: first, as collection and distribution centers for agricultural products and consumption goods, and second, as centers for nonfarm employment and concentrated markets for locally produced goods and services. Secondary roads, connecting rural centers to the national economy, and farm-to-market roads, connecting farms to rural centers, are critical to the effective functioning of these centers (*17*).

STUDIES OF SERVICE AVAILABILITY, MOBILITY, AND MIGRATION

A comparison of data from studies carried out in nine Indian states, under the sponsorship of the Indian Roads Congress, showed a linear relationship between road density and literacy rates (*18*). On the basis of a relatively small number of cases, road density was found to be closely related to postal services, while correlations with primary school and health center availability were weak, reflecting that such services are already more widespread in rural areas than are roads. These results were based on single-variable regression analyses using primarily cross-sectional data.

The SEATAC study (*19*) showed that government officials, especially ones close to the service-providing level, often capitalize on improved accessibility first by providing mobile services, such as agricultural extension, mobile health units, and postal services. In addition, greater accessibility tends to attract more highly qualified professionals, such as teachers and doctors, to formerly isolated areas, as well as to ensure more reliable supplies and supervision. These factors are likely to encourage greater service use, which in the long run may lead governments or communities to invest more in fixed facilities.

However, the response of government services is only a small fraction of the total response of the community to accessibility change. A more significant change noted in the SEATAC study was the increased presence of traders and businessmen in the formerly isolated communities. This increase coincided with the availability of more diverse and reliable goods in local markets, and more information about the outside world, including the prices of cash crops, market opportunities, new ways of doing things, new products to buy for both production and consumption uses, and travel and employment opportunities.

The SEATAC study also found a pattern of small scale migration into the study areas by commercial farmers, traders, and nonfarm entrepreneurs, and an increase in travel out of these areas by local residents, but no major rural-urban migration effects because of accessibility change. The report cited the lack of certain push factors in the study areas, such as high population density, which might lead to a greater migration response in other circumstances. Mobility was increased for rural inhabitants to locations outside the study areas for shopping, marketing, personal travel, and job seeking. Mobility also increased for individuals from other locations coming into the study areas.

Another way to evaluate the impacts of access change is to model its effects on the determinants of personal mobility in rural areas. Rahkonen et al. (*20*) studied personal mobility patterns in a rural area of Mexico in relation to household and community access measures. The study found that more than half of all rural travel was employment related, and was principally determined by household socioeconomic status rather than by community access characteristics. In contrast, general purpose travel was more closely related to access characteristics and consequent transport costs.

Throughout the area, farmers who had adequate land to feed their families and generate a marketable surplus felt less need to undertake work-related travel, whereas farmers with only marginal amounts of land found it necessary to work as wage laborers to make ends meet. The study showed the existence of a segmented labor market; workers in communities with poor road access were constrained to take low-paying local farm employment opportunities, while workers in communities with good road access had options to work within a much wider area, including nonfarm employment (mostly construction) opportunities in rural and urban centers. As a result of this less-constrained labor market, wages for farm labor were also higher in these communities.

The study also found that communities without road service had more agricultural activity and less involvement in wage labor than communities close to a road. Smaller average farm sizes and higher proportions of landless households were found in the areas with road access to local and regional labor mar-

kets. The survey data suggest that poorer households, as they are pushed off the land, tend to migrate toward communities with good road access to gain a broader range of employment opportunities.

The Mexico study attempted to use factor analysis to develop an inductive model of rural mobility from data on a large number of interrelated variables. Four factors, explaining 90 percent of the variance, could be characterized as (a) subsistence agriculture, (b) commercial agriculture, (c) land ownership, and (d) livestock activity. The addition of two more factors, wage labor and household life cycle, explained 100 percent of the variance. When household factor scores were calculated, the wage labor factor was the most important single determinant of work-related travel and the only factor positively associated with this behavior. However, the factor analysis approach tended to obscure the detailed relationships underlying personal mobility in the study area.

In the context of Colombia, Udall (*21*) also explored the relationship between farm income, accessibility, and urban-rural migration. He found it necessary to define accessibility in two ways: first, in terms of distance to urban centers, and second, in terms of the frequency of bus service.

$$\ln S - \ln M = \ln N \tag{2}$$

$$\begin{aligned}\ln M = {} & m_0 + m_1 \ln E + m_2 \ln A \\ & + m_3 \ln (A^2) + m_4 \ln \mathrm{DB} \\ & + m_5 \ln \mathrm{DB} + m_6 \ln \mathrm{DC} \\ & + m_7 \ln \mathrm{DR} + m_8 \ln B \\ & + m_9 \ln C + m_{10} \ln y\end{aligned} \tag{3}$$

$$\begin{aligned}\ln N = {} & b_0 + b_1 \ln Z + b_2 \ln E \\ & + b_3 \ln \mathrm{SH} + b_4 \ln F + b_5 \ln \mathrm{MC} \\ & + b_6 \ln \mathrm{LH} + b_7 \ln A + b_8 \ln T \\ & + b_9 \ln \mathrm{DB} + b_{10} \ln \mathrm{DC} \\ & + b_{11} \ln \mathrm{DR} + b_{12} \ln B \\ & + b_{13} \ln y\end{aligned} \tag{4}$$

where

S = labor supply,
M = migration rate,
N = number of family members in the countryside,
E = maximum level of education,
A = age distribution of household,
DB = distance from Bogota,
DC = distance from nearest small city,
DR = distance from nearest road,
B = bus service frequency,
IC = interaction of bus service and DC,
y = per capita family consumption (income proxy),
Z = cultivated land area,
SH = sex of head of household,
F = fertilizer use (dummy),
MC = machinery use (dummy),
LH = hired labor, and
T = tenancy (dummy).

This cross-sectional study showed that, contrary to the conventional wisdom, migration rates increased with distance from cities, but that the strength of this relationship declined with increasing frequency of bus service. That is, for people in remote areas, the value of access to urban job opportunities and amenities overrides the migration cost constraint, but that where frequent bus service is available, adequate access to these opportunities and amenities may be achieved at a lower cost than by migrating.

This study confirms findings in the SEATAC study and elsewhere that long-term migration is more likely to take place where transport options are limited, whereas improvement in rural transport services tends to encourage travel or short-term migration rather than a permanent change of residence.

STUDIES OF TRANSPORT AND COMMUNICATIONS EFFECTS

Since the 1960s, research has been carried out on the relationship between transport and telecommunications (*4*). A certain degree of substitutability between these means of communication has been noted for information flows such as health, education, and economic news. However, the stronger relationship found has been one of complementarity. For example, Owen (*4*) noted a greater number of radios present in areas of better road accessibility and, on the other hand, greater road travel to and from towns with more radios. It has also been found (*20*) that rural people would travel up to 30 km to use rural public telephones, and that telephone contacts frequently resulted in additional personal travel, especially as telephone contacts were used to pass on critical information about family emergencies and job opportunities. Improved information flow reduced the uncertainty involved and therefore enhanced rural people's willingness to take trips in cases where there could be no substitute for physical transport (e.g., laborers traveling to distant job sites).

The SEATAC study systematically traced the changes in information flow that followed transport improvements and their economic consequences for rural areas. For example, pepper planting spread rapidly in Sarawak because of increased knowledge of pepper planting technology, prices, and markets that flowed along the routes of increased transport accessibility. Expanded information flow also had social, political, and cultural implications, leading to more active participation by rural people in the decisions that affect their lives and an increased awareness of options other than traditional behavior. Learning about the opportunities offered in the wider world provided an additional incentive for more personal travel. The feedback effects of improved information flow, with resulting economic and social development multipliers, may prove far more significant in the long run than the direct economic effects of transport improvements.

Organizational changes have also been noted as a response to transport improvements, such as the development of farmers' cooperatives in India (*4*). These organizational changes may reflect new information about the advantages of cooperative organization, or the application of a known organizational technology to capture a share of the profits generated by reduced transport costs. The increase in traders visiting

rural areas with improved accessibility assures more competition and changes the economic structure in ways that should lead to more economic efficiency in trade and lower prices for the rural residents as well as for the traders. Other changes in social organization will occur in the longer term for these communities, but it is difficult to separate the organizational response to transport changes from changes that are because of more general increases in the wealth and welfare of the community.

Organizational changes can also occur on a regional or national scale. Such changes are often described in terms of market integration or nation-building. These are system-wide effects that result, in part, from changes in the transport system to increase accessibility. Such changes are considered desirable by national level planners because of the development feedback effects they imply. However, there are few research findings to support a quantitative estimate of these benefits, which are difficult to measure (*11*,*22*).

ACCESSIBILITY MODELING AND IMPACT

The SEATAC study formulated and tested a model of rural transportation impacts of different types of transportation improvements on income distribution and quality of life in rural areas of four Southeast Asian countries, within a common conceptual framework. The major contributions of the SEATAC study were

1. To explicitly formulate a model of the impacts of rural transportation improvements,
2. To relate the impacts of rural transportation improvements to accessibility change measures,
3. To trace the impacts of the flow of information as well as of material goods and people, and
4. To explicitly identify the roles of intervening variables in conditioning impact outcomes.

Five types of accessibility were identified and defined by the authors in the SEATAC study as follows:

1. Market access is the inverse of travel time from the principal market serving the village (farm) to the principal (regional) center outside the study area.
2. Village access is the inverse of travel time from the village (farm) to the principal market.
3. Trip access is defined as a combination of market access and village access, weighted by the average of short- and long-distance trips in the total (trip) sample.
4. Service access is defined in terms of the frequency of visits to a village (farm) by extension services, health services, and traveling traders.
5. Household access is the combination of trip access (access out) and service access (access in).

Clearly these definitions focus on the farm household unit and were not designed to refer to an industrial unit handling bulk commodities. Different accessibility measures, such as cost or generalized cost, may be more appropriate for industrial shippers of bulk commodities that are not time sensitive.

Changes in the rural economy were found to be related to changes in accessibility in different ways, depending on the type of accessibility that had changed. For example, a transport improvement that significantly reduced travel times between a rural center and the primary network was likely to result in increased availability of goods and services in the rural center, while a decrease in travel time between villages and rural towns was more likely to induce additional travel by village residents.

Accessibility can be defined in cost terms as well as time. Liang's (*8*) work in China defined accessibility as the inverse of total transfer cost (transport plus handling), relating to road, rail, and river transport. Clearly, transport cost change must be part of the impact model, but it does not have to be defined as accessibility.

The recent attempts to model the effects of road availability on the provision of services have not been successful (*23*). One reason for this lack of success may be the specification of the independent variable in terms of road density rather than in terms of accessibility change. There is no obvious link between road density and the reasons why officials would choose to locate service facilities in particular places. However, it could be hypothesized that access change could trigger a response by government officials to take advantage of newly created opportunities. This is one example where substitution of a cross-sectional analysis for a longitudinal analysis without a theoretical model has weakened the explanatory power of regression results.

A further problem with these studies is that government response to transportation change depends on a number of variables, not all of which are directly related to accessibility. Decisions to invest in schools, post offices, and other services are made by civil servants who must consider a number of factors, including pressure from citizen groups and influential inhabitants of the area, as well as the availability of central and local funding. These noneconomic factors can create sufficient noise to prevent a simple bivariate regression model from producing statistically significant results.

Some of the studies of rural transportation impact (*23*) refer to increased accessibility as if it were a positive impact by itself. This approach is taken from traditional urban transport analysis where accessibility is used as a proxy for other expected effects in a type of multicriteria approach to transport planning. Although increased accessibility does have some intrinsic value to rural residents (which can be thought of in terms of the option value associated with personal travel or emergency transportation), it is not very useful as an impact measure unless it can be linked to changes in activities that can be more directly related to improved rural welfare.

Accessibility modelers should also take into account that the impacts of transport improvements can have both negative and positive effects on different groups in the population. For example, the SEATAC study found that rural transport improvements in Sarawak gave local fishermen in some locations new access to the Singapore market (*19*). This increased the amount of fish harvested and increased incomes for fishermen. However, it also increased the prices of local fish and made fish harder to obtain for the local population. Consequently, some households gained and some lost in terms of the net change in standard of living for the rural population. These distributional effects create additional problems for the measurement of costs and benefits associated with a change in transport accessibility.

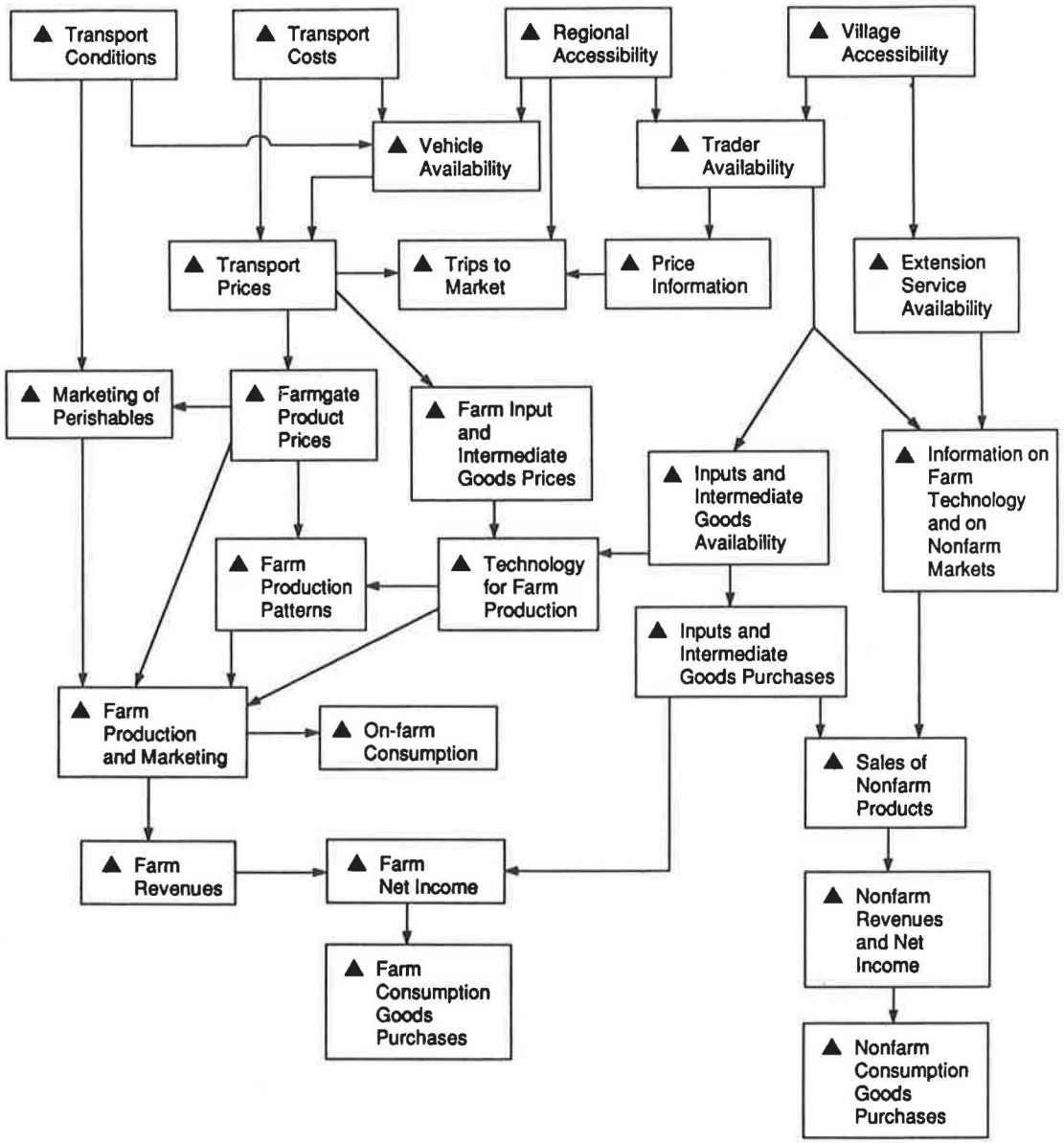
FORMULATION OF AN IMPACT MODEL

The impacts of rural transportation improvements can be seen as a result of the interaction of many factors as shown in Figures 1–3. These figures incorporate the relationships suggested by the research previously described, and illustrate the sequences of effects that are not presently shown by the simpler impact models used in recent quantitative research. Figure 1 deals with short- and medium-term impacts related to changes in goods transportation that occur within 1 to 5 years of the change in access. Figure 2 shows the short- and medium-term changes related to personal travel, and Figure 3 traces longer-term indirect impacts resulting from the medium-term changes.

The objective of these flow charts is to describe the causal linkages that are involved in each step of the impact process to assist researchers in the specification of causal models. The mediating variables that condition the magnitude of the impacts in each category are included.

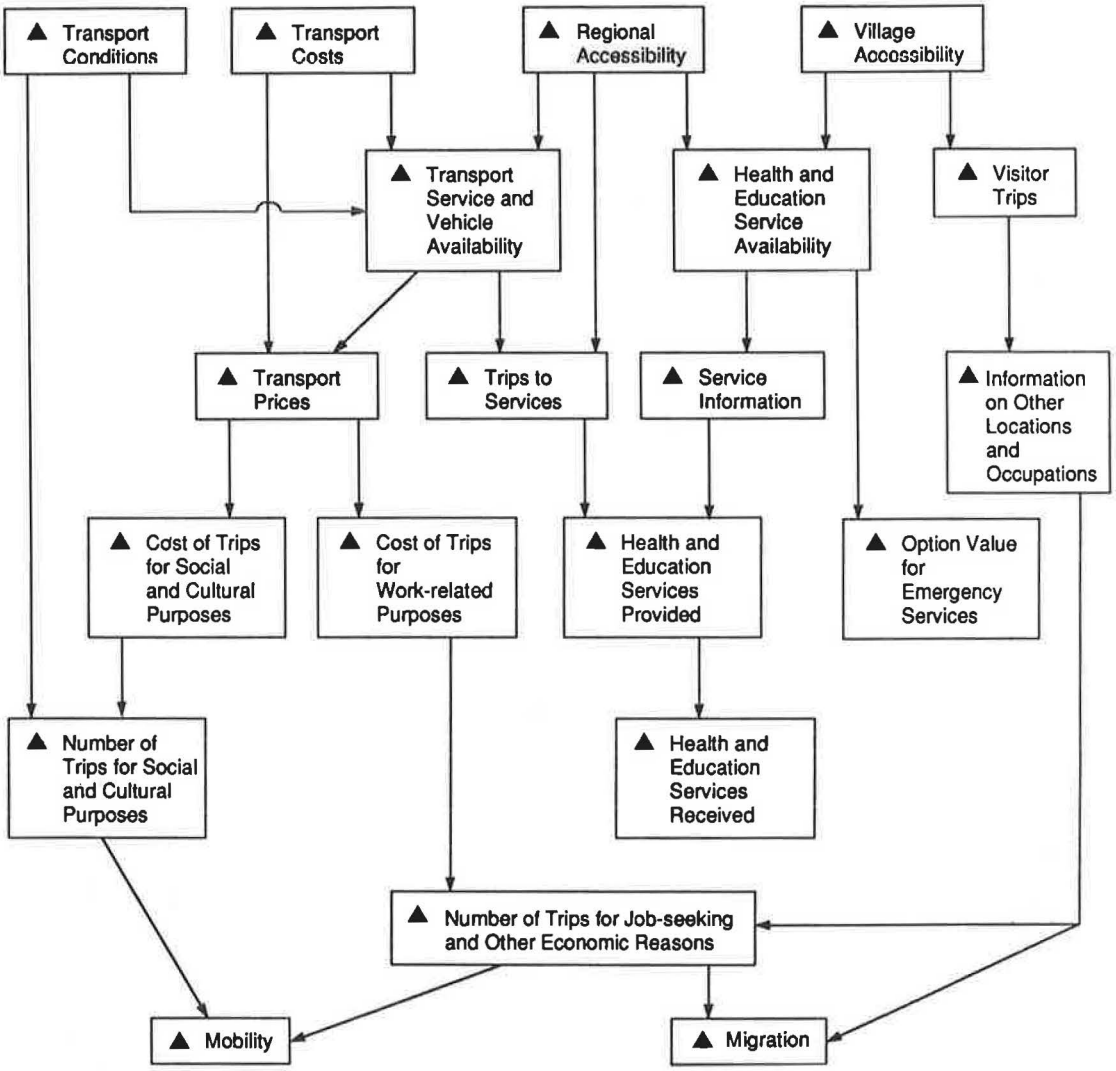
Short- and Medium-Term Goods Impacts

Four changes directly due to rural transport improvements are shown as the starting point for goods-related impacts in Figure 1: (a) change in transport conditions, (b) change in transport costs, (c) change in regional accessibility, and (d) change in village accessibility. Changes in transport conditions



Note: Boxes referring to "Farm" also apply to mining, fishing and forest production.
▲ = change

FIGURE 1 Short- to medium-term goods impacts.



Note: ▲ = change

FIGURE 2 Short- to medium-term mobility impacts.

include such effects as the reduced roughness of a paved road compared to a gravel road. This type of change, combined with the time savings of transport on a paved surface, can lead to a decrease in damage and spoilage of goods and have a strong impact on the transport and marketing of perishable commodities such as meat, fish, milk and dairy products, eggs, fruits, and vegetables. These changes have a less-marked effect on the transport of nonperishable bulk commodities such as grains, tubers, bottled beverages, cement, fertilizer, petroleum products, and building materials.

A decrease in transport cost is the most commonly used variable for evaluating the economic impact of rural transport improvements. This decrease reflects cost savings accruing to transporters from decreased wear and tear on their vehicles and decreased use of transporters' travel time. Part of this cost saving, under competitive conditions, is passed through to shippers in the form of lower transport prices. Lower transport costs may also encourage an increase in the number of transport service providers (and vehicles available in rural centers), leading to more competitive conditions, which in turn affect the prices charged for these services.

The decrease in prices charged by transporters leads to higher farmgate product prices and lower-cost farm inputs, which in turn lead to greater farm production. These relationships form the basis for the classical rural transport impact model.

A similar line of reasoning applies to the effects of transport cost changes on other primary economic activities such as small-scale mining, fishing, gathering of forest products, and craft production from local raw materials, which are not shown explicitly in the flow chart, but are likely to occur in both agricultural and nonagricultural zones influenced by the transport improvement. The impacts of transport changes on these

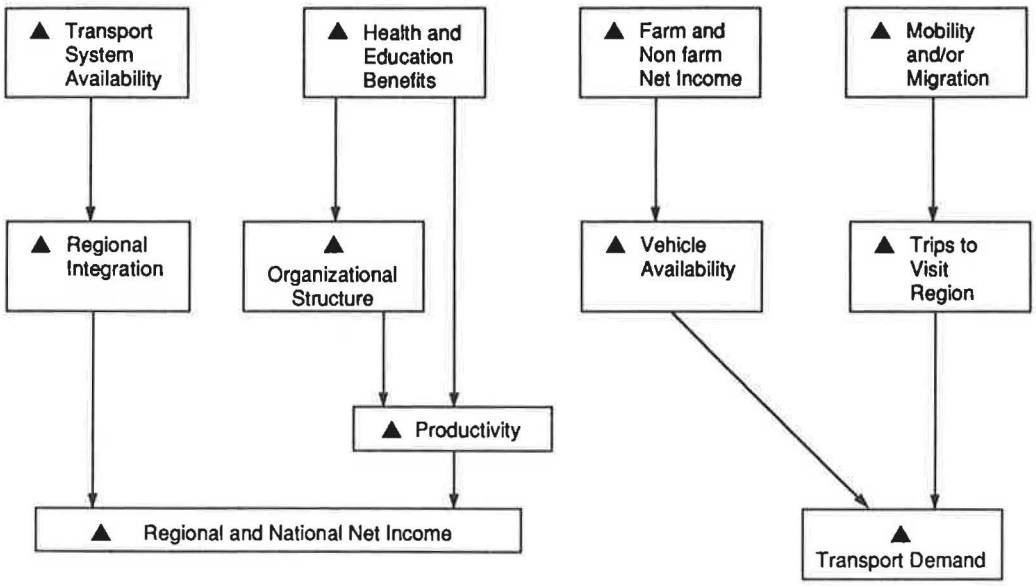


FIGURE 3 Long-term impacts.

activities can be treated in the same way as agricultural change, by assessing the effects on the production and marketing of these products.

The induced changes in production patterns may decrease the output of some goods (e.g., subsistence crops) to increase the production of others (e.g., cash crops) as shown in Figure 1. This will affect the pattern of on-farm consumption as well as cash income for the farm household. In principle, the net welfare of the household should be increased as a result of this change. In practice, however, the effect may be to increase the welfare of the household member who controls the cash flow, at the expense of other household members. Also, there are different effects on those households that are in a position to take advantage of the opportunities (e.g., progressive farmers or those with capital to invest), which leads to differences in the effects of these changes among household groups.

A change in regional accessibility (defined as a reduction in the travel time between the market center within the production zone under study and the outside world—either a regional center or a junction on the primary transport network) is closely related to changes in the availability of outside goods and traders in the market center and the availability of transport services and vehicles from outside to the market center. The expanded availability of outside goods brought in by the traders and the increased market prices in a market center with a transport improvement lead to an increased number of trips from farm to market (both local and outside) and an increase in the consumption of inputs and intermediate goods and services from outside the rural area. Eventually, increased access also leads to the establishment of more social and economic support facilities in the market town, such as schools, health services, credit facilities, equipment suppliers, and equipment repair. These market towns may evolve in the direction of becoming rural centers, providing nonfarm employment opportunities in response to the demand generated by increased farm income.

A change in village accessibility (defined here as a reduction in travel time from villages to a market center, or accessibility within the zone of study) is also related to a greater availability of traders who are attracted by a higher number of products in the market. The presence of more traders leads to better price information and access to better prices for marketed rural products, inputs or intermediate goods, and consumption goods. Improved village accessibility also leads to the increased presence of mobile service providers in the village, such as agricultural extension workers, who bring information to the village concerning prices, markets, and production technology. This communications linkage facilitates the diversification of local production and increases local demand for farm inputs and nonfarm products. Increased sales of nonfarm products lead to increased revenues and net income for nonfarm businesses, and a resulting increase in nonfarm consumption goods purchases (*16*).

Short- and Medium-Term Mobility Impacts

In addition to the effects on local production and consumption of goods described in Figure 1, there are several personal mobility impacts related to the four types of transport changes, as shown in Figure 2. The change in transport conditions, which affects the comfort and convenience of travel as well as time savings and a greater availability of vehicles or transport services in the study zone, leads to a greater number of trips made by local residents. These trips may be made for economic reasons (marketing, credit, employment) or for social and cultural purposes (visiting family, trips to outside services, dealing with administrative matters) or both.

Changes in transport costs usually influence prices charged for transport services (bus and taxi services), and also affect the cost of owning and operating a means of personal travel (motorcycle or bicycle). As with goods transport, better transport conditions, lower transport costs, and increased regional accessibility lead to a greater availability of passenger vehicles and transport services, and this greater availability increases competitive conditions that in turn lead to more cost savings passed through to travelers. The resulting lower cost for trips leads to a greater number of trips for social and cultural purposes and a higher personal mobility as shown in Figure 2.

Changes in village and regional accessibility both play a part in inducing change in rural travel patterns. To the extent that changes in accessibility result in increasing availability of health and educational services in the rural centers, they are more likely to induce village-to-rural center travel than rural center-to-outside center travel. However, an increased flow of information regarding goods, services, and activities available in outside centers (partly as a result of increased trips from outside visitors), coupled with improved regional accessibility, may induce a certain amount of additional travel to outside centers, even in the absence of improved village accessibility. Similarly, village access improvements will have only a limited effect on longer distance travel if access of markets to outside centers is not adequate. However, the combination of improved village accessibility and improved market accessibility can have powerful effects on rural mobility and consequent changes in the rural economy, and somewhat lesser effects on rural migration.

Rural people make trips for a variety of reasons and often combine several purposes in one trip. However, for the purposes of modeling, it is convenient to divide rural travel into two categories: work-related and other. Work-related trips include trips to buy farm inputs and sell farm products, trips seeking credit and other economic services, job seeking trips, and trips for off-farm employment (both farm and nonfarm). Other trips include trips to utilize health, education, or administrative services, trips to visit or accompany family members or friends, and trips to participate in group activities of social or cultural significance. All of these trips generate welfare for the traveler and others (otherwise they would not be taken), even though it is difficult to quantify or attribute a value to these positive effects.

Rural road studies using currently accepted approaches have consistently underestimated the magnitude of the personal mobility-related response to road improvements. This response seems to occur even when there is no significant increase in local incomes, which could account for the increased consumption of personal travel. The failure of current models to predict mobility impacts is primarily because these models fail to recognize the value of time to rural households, including the values they attach to time spent in activities other than economic production and consumption. Significant time savings, even when combined with increased financial outlay (as when one shifts from walking to using a bus service), appear to induce major changes in travel behavior on the part of rural people.

Models of personal mobility are commonly applied in urban transportation analyses, but may need to be reformulated for application to the rural context. Many of these models are data-demanding and therefore difficult to apply in a rural setting. However, one model that appears promising for this type of application is the unconstrained gravity model (sometimes referred to as the direct demand function) described by Quandt (*24*). This model forecasts trip generation as a function of accessibility and socioeconomic characteristics of the origin and destination areas, reducing the constants for which the model must be calibrated in a given case to a small number. As far as is known, this model has never been applied in a study of farm-level rural transport in developing countries. This lack is probably for good reason, because the Mexico mobility study shows that work-related trips, which are the majority of trips, are not a simple function of accessibility measures. Other trip types, however, are closely related to accessibility.

Long-Term Impacts

Building on the short- and medium-term impacts described herein are a number of longer-term impacts that may take 10 years or more to appear. Some of these impacts are shown in Figure 3, which starts from the income, service utilization, and mobility impact outcomes already shown in Figures 1 and 2. Effects, such as regional integration, greater productivity, and greater income because of feedback or multiplier effects in the economy, are more diffused than the short-term impacts.

These impacts are hard to measure in the normal time frame of rural impact studies. Because of their longer time frame, such impacts are also more difficult to separate statistically from the impacts of nontransport activities or changes. An attempt to deal with the long-term impacts of infrastructure on regional integration is provided elsewhere (*22*). However, this study does not distinguish between the effects of transportation and other types of economic infrastructure, and it estimates impacts at a higher level of aggregation than the models presented herein.

ROLE OF MEDIATING VARIABLES

Mediating variables, including situational factors and socioeconomic structures, are characteristics of the rural setting that act as constraints on the magnitude of the response of different rural areas to accessibility change. An outline of the mediating variables follows (*19*):

A. Situational Factors
   1. Physical Characteristics
      a. Terrain
      b. Soils and geomorphology
      c. Hydrology
      d. Climate and rainfall
      e. Vegetation
   2. Population Characteristics
      a. Size and growth rates
      b. Density
      c. Age/sex structures
      d. Socioeconomic groups
      e. Ethnicity
      f. Religion
      g. Nationality

B. Socioeconomic Structures
   1. Economic Structure
      a. Land tenure
      b. Land use
      c. Investment in rural industries
      d. Patterns of employment
      e. Structure of transport service sector
      f. Pricing/marketing/storage systems
      g. Credit systems
      h. Tax policies and effects
   2. Social Structures
      a. Settlement patterns
      b. Patterns of association
      c. Formal organizations
      d. Educational levels
      e. Health levels
      f. Social control mechanisms
      g. Information levels
      h. Participation in planning

For example, land tenure may limit the potential change in production patterns, and therefore limit the agricultural production response. Similarly, cultural conventions could limit the amount of personal travel possibly generated by access change for certain population groups. The structure of the transportation service sector may limit the proportion of the transport cost savings that is passed on to the users, thereby limiting the users' potential response to the change. Such mediating variables are important for predicting the differences in responses between different rural areas, and the key constraints must be included in formulating a model to have adequate explanatory power from a statistical viewpoint.

RECOMMENDED MODELS FOR FUTURE RESEARCH

In order to gain accuracy and explanatory power, the types of impact models that should be used in future research in rural areas must have the following characteristics:

- Ability to accept the most appropriate measures of accessibility for the impacts considered,
- Ability to incorporate significant mediating variables or constraints, and
- Statistical reliability in the coefficients or elasticities estimated by the model, as well as correct signs.

Because of the variety of rural transport impacts described herein, it is clear that no single model is adequate to predict them all. Consequently, a combination of models may be the best approach with (a) primary production impacts forecast using a two stage Cobb-Douglas model and submodels of elasticity with respect to accessibility for each major activity (*8*), (b) local manufacturing and consumption forecast with a multiplier model (*16*), (c) personal mobility predicted for work-related trips by using an employment predicting model [possibly based on the farm and nonfarm activity models in (a) and (b)] and for non-work-related trips by using an unconstrained gravity model (*24*) with different accessibility measures for different trip types or distances, and (d) migration forecast by using simultaneous equations on the basis of labor supply and demand (*21*).

In the case of services, including education, health, agricultural extension, and communications, it appears that currently used regression models may have less predictive power than a model based on the actual formal and informal agency rules of service provision relative to accessibility, combined with a model of accessibility change. This combination of models would be much more powerful in explaining the rather complex relationships diagrammed than simpler regression models that attempt to combine a variety of effects.

In many cases, some basic research may be needed to determine model characteristics (such as the Haggblade multipliers), which can then be used by other researchers and planners in broader applications to specific planning areas. Simpler models may also be used in cases where the data are more suited to their use. These choices must be evaluated by the researchers in each specific case.

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