TRANSPORTATION RESEARCH RECORD 820

Land Use and Economic Development

TRANSPORTATION RESEARCH BOARD

COMMISSION ON SOCIOTECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1981

Transportation Research Record 820
Price $5.20
Edited for TRB by Naomi Kassabian

modes
1 highway transportation
2 public transit
3 rail transportation

subject areas
12 planning
15 socioeconomics

Library of Congress Cataloging in Publication Data
Land use and economic development.

(Transportation research record; 820)
1. Transportation planning–Addresses, essays, lectures.
I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 820 [HE152.6] 380.5s [388'.068] 81-22412
ISBN 0-309-03261-X ISSN 0361-1981 AACR2

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Evaluation of Economic and Development Impacts of Major Transit Investments

DOUGLASS B. LEE

Policymakers incorporate information on economic and development impacts in their evaluation of major transit investment alternatives, and there are good reasons for doing so. The information they use, however, is rarely suitable for evaluation. Deficiencies range from highly formal and detailed multiplier analyses that answer the wrong questions to highly heuristic arguments that cannot distinguish one alternative from another. Claims regarding jobs, property values, and urban form, for example, are often spurious. Transportation planners tend to underestimate both the importance of economic and development impacts and the difficulties in evaluating them. The task is to formulate the empirical questions to focus on potential real benefits and to estimate the magnitude of the benefits in the specific case. Precise answers will never be obtained, but at least the analysis can be directed to the applicable concepts.

Economic and development (E&D) impacts are a subset of the indirect effects of major transit investments. Direct effects are (a) the land, labor, materials, etc., acquired to construct and operate the system and (b) the passenger travel that takes place on the system. These direct effects then result in several kinds of indirect effects. Indirect economic impacts include employment, income, occupation, investment, retail sales, and other changes in private market activities. Development impacts are the physical and spatial effects--also called land use impacts (1)--brought about by the construction and operation of the transit system. Other indirect effects include environmental and social impacts. Analysis of E&D impacts can be separated into two parts:

1. What will happen? The positive side of the problem comes in establishing the empirical relationship between the transportation investment and the related impacts. Of particular concern to the federal granting agencies are the necessary conditions under which predicted impacts will occur and the assurance that public actions will lead to those conditions.
2. Which is better? The normative side of the problem is in choosing among transportation alternatives on the basis of E&D impacts as well as travel benefits and costs, i.e., the evaluation of E&D impacts (2).

Although E&D impacts are of significant concern for many kinds of transportation investments, the scope of this paper is limited to transit facilities that have fixed guideways. These include heavy-rail and light-rail systems, downtown people movers, and busways, usually in large urban areas. The lines of reasoning described, however, should apply to any urban passenger mode of transportation.

RATIONALE FOR CONSIDERING E&D IMPACTS

Much analysis of E&D impacts has been generated without thought to the proper questions. To learn that an expenditure of $2 billion will create more jobs than an expenditure of zero dollars (all other things being equal) does not require any analysis at all. Several questions of more pertinence to evaluation are whether the given expenditure will create more jobs, more total income, or a more-equal distribution of income than another equal expenditure. These kinds of questions are both harder to ask and harder to answer.

Whereas theory and methods could be discussed at some length, the best way to motivate interest in the topics is to take some of the claims made for E&D benefits and see what would be needed to evaluate them. The arguments listed below include many that have been used in proposing new transit systems or extensions and a few that have not. All the arguments are valid under suitable conditions and not valid under other conditions, so evaluation of the arguments will depend on empirical information regarding whether the suitable conditions apply to the specific case. Examples will be offered, but no attempt is made to judge the correctness of past or proposed transit projects. The object is to outline the rationale for including E&D impacts in the overall analysis of the investment's worth.

Because of their indirect nature, E&D benefits should not be used as a substitute for travel benefits. In other words, if a project cannot be justified on the grounds of travel, it should not be treated as a transportation project. When travel projections are dependent on land use changes that are a consequence of the transit investment, clear documentation of the positive portion of the impact question (what will happen) is essential, even if no economic or land use benefits are claimed. The most important potential role for E&D benefits is probably in the justification of the incremental costs of a heavy capital investment (such as rail) over a lower capital alternative.

REVITALIZE URBAN AREAS

One of the more popular rationales, the use of public investments to revitalize sections of central cities, has been in use for several decades under various labels. The intent is to transform an area that has become blighted or depressed into one that is economically sound and self-sufficient. Redevelopment and rehabilitation are the main mechanisms, and public-sector actions are designed to stimulate private investment. Other related objectives include the improvement of urban neighborhoods, reduction of crime and vandalism, encouragement of owner investment and maintenance, reduction of unemployment, and the fuller use of the excess capacity in public facilities.

Urban revitalization, assuming that it can be successfully accomplished, can be judged from several perspectives. The federal government may be concerned with whether a transit investment in Boston will result in more urban revitalization than an equal investment would in Cleveland. Or the relevant question may be whether a transit investment would result in more revitalization in Cleveland than a highway or an urban-renewal investment would in the same city. The Urban Mass Transportation Administration (UMTA) may be interested mainly in whether a heavy-rail investment would do more revitalization than would a light-rail investment in the same city. The suburban taxpayer may question whether the investment in the central city creates more jobs than would a private investment in the suburbs. Any or all of these perspectives may help illuminate the choice between one alternative and another.

Rebuild Central Cities

To the extent that an urban revitalization effort stimulates private investment in the central city, some of this investment would already have taken place elsewhere in the region; thus the result is an intraregional transfer. The evaluation question is why the investment is better in the central area than elsewhere. One argument is that a public infrastructure would not have to be built if existing excess capacity within the central area is used rather than new areas on the fringes. In Detroit, it has been acknowledged that there is excess capacity in the suburbs as well (3), so this factor did not contribute to the revitalization benefits of the proposed light-rail system. Another argument is that low-income groups and minorities will benefit, which will result in an improvement in distributional equity.

Even though the investment shift is an intraregional transfer, the claim can be advanced that coordination of the investment will create greater net benefits. In Detroit, for example, the minor loss of investment to the suburbs will (purportedly) be offset by large gains to the central city, and the suburban losses are not in absolute terms but in a lower rate of growth. Thus, much can be gained at little cost. Demonstrating the plausibility of this assertion calls for comparisons of multipliers, markets for land uses in different locations, synergistic development effects, etc., that show central cities to be more socially productive investments than suburbs.

Stimulate Private Investment

Ever since the concept of urban renewal was initiated, it has been found that public investment does not always (and perhaps seldom does) stimulate private investment. Either no private investment may take place or the same private investment would have taken place in the same manner without the public investment. It may never be possible to identify the exact amount of private investment induced by any particular public investment, but at least we currently have a reasonably good idea of how projects can be undertaken jointly and benefit both public and private sectors.

Evaluation of the leveraging effects of public-sector investments depends heavily on market assessment and documentation of the entrepreneurial activities being undertaken by the public sector. Methods for market analysis showed, for example, that a light-rail investment in Detroit's Woodward corridor would have a greater stimulus on private investment than in any other corridor within the city (3). Induced private investment in the form of improved maintenance and upgrading of homes and stores may stem from the presence of a new transit facility, from reduced street congestion within the neighborhood, from additional services and neighborhood amenities, or from the redevelopment of key blighted parcels. How much of a public-sector effort is needed to tip the balance in favor of increased private investment can be a subtle assessment that calls for solid market information plus informed expert judgment.

STRENGTHEN LOCAL ECONOMY

Any expenditure will have direct effects (purchase of labor and materials, land, etc.) and multiplier effects (direct recipients of the expenditure will spend their income on other labor and materials). The more open (generally smaller) the local economy is, the greater is the tendency for leakage (propensity to spend outside the region) and the lower is the multiplier (4,5). As when a rock is thrown into a pond, there are a splash and some ripples.

If a worthwhile evaluation question regarding these direct and indirect effects can be found, it is in the nature of whether one kind of expenditure creates more beneficial ripples than another. For example, attention might be given to whether a transit investment will create more jobs than an equal expenditure by the private sector in the same community would. Different results may be obtained for the number of new jobs, the total amount of labor income, and the number of jobs for previously unemployed residents. Contrary to the usual consensus among analysts, it is easier to estimate gross effects of major expenditures than differences between types of expenditures. It is practically impossible to determine whether a heavy-rail system creates more income than a light-rail system of equal nonlocal investment does. Ultimately, the answer hinges on which system serves the local economy most efficiently, and multiplier analysis can only weed out those that are obviously of no value.

Improved access benefits business (as it does to almost everyone), but these benefits must be weighed against the costs. Even if the costs are indirect (e.g., through property taxes) or only opportunity costs (a different expenditure would create more benefits), more access does not necessarily stimulate the economy. Moreover, access benefits are reflected in travel, and claiming additional benefits for access is double counting. Increased retail sales could indicate a stronger economy, but (as with too many indirect effects) net gains (as distinct from the spatial redistribution of sales) can only be established by reference to the overall efficiency of the transportation alternative. The question of global efficiency is among the most difficult to answer.

Better Use of Local Resources

Factors of production can be grouped into those of labor, capital, land, materials, and entrepreneurship. Those factors in scarce supply must be economized, and those with which the region is relatively well endowed should be turned to advantage. A transit system that helps reduce the spatial separation between workers and the most suitable jobs improves use of the local labor pool. Stimulation of demand for sectors that show excess capacity improves use of capital. Planned development and reduction of energy use in passenger transportation may release more petroleum for other purposes. Often overlooked, the encouragement and effective use of scarce entrepreneurial talent may be the most productive way to strengthen a local economy.

If transit investment can have an impact on making better use of scarce resources, it will take place in the details of the planning and implementation of the transit project (6). Station locations that provide the best opportunity for joint development, station-access designs that preserve neighborhood amenities, and alignments that provide the best service in the long run rather than simply show the lowest public expenditure are some of the microscopic decisions that will determine whether the net effects on use of resources are positive or negative.

Reduce Unemployment

An expenditure of federal funds in an urban area will not reduce unemployment there if (a) the local unemployed have no skills applicable to the contemplated projects, (b) most of the workers are hired from outside the region, (c) there are discriminatory barriers to hiring the unemployed, or (d) the work can be highly automated (7). Even if the pool of unemployed can be clearly matched to the demand for labor generated by the federal expenditure, the reduction in unemployment might be less than if (a) the expenditure were made in the private sector, (b) the expenditure were made on some other transportation project, or (c) the expenditure were made in another city. The existence of a pool of unemployed workers does not imply that there will be any employment benefits emanating from a transit project.

When it can be assumed that some similar federal expenditure would have been made in the region under any likely circumstances, employment effects are mostly intraregional transfers. If the expenditure would have occurred in another city, then the effects are interregional transfers. The applicant for federal funds should address the question of the effectiveness with which the expenditures will reduce unemployment in the local region relative to other local (including private-sector) expenditures.

Expand Tax Base

A transit investment that creates net benefits to a region will inevitably increase the tax base of the region. Unfortunately, there is no reliable way to establish the quantitative magnitude of any net benefits. Most of the analysis that can be done with respect to tax bases (property, sales, and income) measures shifts in the location and in the components of the tax base. A transit investment that causes property values to increase in one community will increase that community's property-tax base, but this is likely to be at least partly at the expense of some other community in the region. The same will be true for sales taxes and perhaps for income taxes. The transit system itself, of course, subtracts from the property-tax base in that it removes land from tax rolls, although it may remove less land than would a highway of equal capacity.

Because quantitative estimates of net gains (or losses) to the tax base are so unreliable, analysis is better directed at the equity impacts. Tax rates in communities that gain or lose taxable property or activities will be affected, and the intraregional redistribution of the tax burden may be favorable or unfavorable.

Enhance Regional Advantage

A plausible hypothesis regarding the San Francisco Bay Area is that the city needed a high-capacity and high-quality commuter transit network in order to maintain its comparative advantage as a West Coast financial center (8). Bay Area Rapid Transit (BART) provided the necessary complement to the region's already established natural advantage. From the standpoint of the country as a whole, enhancing the special characteristics of San Francisco adds strength to the national economy. None of these assertions can be tested empirically, and there is little reason to waste time and effort in doing so. Certain aspects, however, can be documented, which lends somewhat greater (or less) credence to the arguments. Market Street and San Francisco's financial district added large amounts of high-rise office space during and after the construction of BART (9), and surveys of ridership suggest that an expanded freeway-automobile mode could not have served the current high-intensity use of land without destroying the city. There are those who decry this "Manhattanization" of San Francisco, but, be that as it may, BART was almost certainly a necessary ingredient. Whether an express-bus system could have done just as well is a harder question to answer.

An alternative approach to strengthening the local economy is to diversify into sectors that are less sensitive to cyclical swings, or faster-growing, or more complementary to existing sectors. Transit investment might serve this objective by supporting office employment in a manufacturing region (10) or by supporting urban life-styles that would not exist without special or high-capacity transit modes. Many factors must be brought together to induce these effects, but transit may be an essential component.

PROMOTE EFFICIENT DEVELOPMENT

Some planners have long subscribed to the notion that fixed-guideway transit can shape development patterns, which give form to the metropolitan area. There may be considerable truth in this, but recent impact studies have found the detectable effect to be small in the short run in the U.S. cities (11-15). The reasons for this are numerous, but two of the most important are (a) the universal availability of highway modes of travel (which forces the new system to compete for travelers in a market already supplied with substitutes) and (b) the absence of local land use policies that would lead to altered development patterns (16).

Although it is rarely acknowledged, the argument that favors transit investments as a means for affected regional development patterns must be made largely on second-best grounds. Urban sprawl is the result of underpriced highway and other public infrastructure services (17), and these public costs can be reduced by encouraging transit-oriented nodes of development. Environmental quality can be more easily protected by using clustered development rather than by uniform low-density development or unplanned sprawl. A high-density urban core (which would occur naturally under the best conditions) can be built with the aid of a major transit investment. These arguments have merit, but they are extremely hard to substantiate.

Reduce Sprawl

It is easier to explain the causes of sprawl than to measure the inefficiencies, although we have some idea of the types of costs involved (18). The most easily measured factors are those of transportation, urban services, sewer, water, utilities, and fire protection. Social services may also be cheaper on a per-customer basis, and multifamily housing is cheaper to construct per unit. If other factors are held constant, the costs of these inputs increase for either unplanned development or low-density development.

Presumably, however, there are benefits to the individual from low-density sprawl; otherwise, the market would offer something else. These benefits might be more space, fewer restrictions on the use of land, or greater physical segregation. The second-best rationale for countering the tendency toward sprawl is that these individual benefits (if we can describe them) are purchased at too low a price because of government subsidy. The prices cannot be easily corrected, but a counterbalancing effect can be achieved by subsidizing high-quality rail transit. Unfortunately (as may have been the case with BART), transit can serve to increase sprawl if the underlying incentives are left untouched.

Permit Complex Integrated Development

A major transit investment may create an opportunity for mixed-use development that would not have occurred without the transit investment. As is now well known, complex development of this type will not happen automatically just because a rail transit station appears, but the opportunity may be there. Taking advantage of the opportunity requires supportive transportation and land use policies as well as active joint-development efforts under favorable market conditions (19,20).

The main reason for the substantial amount of effort necessary to produce transit-oriented land use adaptations in this country is the general ambivalence of public policy toward passenger modes. In the last three decades, there are probably no instances in which fixed-guideway transit was constructed in an area not adequately served by highways. Much of the extensive BART system was built at the same time that suburban freeways were built; often the rail tracks were in the median of the freeway. In contrast, as observed by Michael Goldberg of the University of British Columbia, rail extensions in Toronto may have had such apparently strong land use effects because the actors involved knew that suburban freeways would not be built.

The benefits that can be cited for integrated mixed-use development are the magnetic effect for attracting related private investment, the reduced requirements for access and parking at stations, the improved utilization of the transit system, opportunities for urban design and public amenities not otherwise available, agglomeration economies in retailing, removal of barriers in the form of fragmented land ownership, and the provision of housing for low- or moderate-income families or for the elderly. These are only opportunities for improved land use development, and they may be found in suburban as well as central-city locations, but they are frequently opportunities that can only be achieved by joint development in conjunction with high-capacity transit modes (21).

Evaluation depends most heavily on assessing whether market conditions and public actions are sufficient (and necessary) to lead to the development results anticipated. As distinct from urban revitalization, integrated development involves making best use of market forces rather than attempting to turn them around. Hence, a much larger share of the investment in the revitalization setting will need to be public investment. Joint development in an area that is not blighted should depend primarily on the private sector for capital, and there should be suitable integration and controls initiated by the public sector.

IMPROVE DISTRIBUTIONAL EQUITY

Many of the reasons--both explicit and implicit--for investing in major transit systems are to help low-income and minority individuals and families, but such results are far from automatic. Construction jobs are transitory and may go to interregional migrants before local unemployed are absorbed. Effects of minority contracting may be very superficial. Neighborhood revitalization may do nothing for the residents if they are renters rather than owners. Redistributing income-in-kind through transit projects may be the most effective mechanism that is politically feasible, but care must be taken to see that (a) the ostensible beneficiaries do in fact receive the benefits and (b) the transportation purposes of the investment are not seriously compromised. If (b) cannot be satisfied, there are generally much better ways to redistribute income than indirect economic impacts of transit investment.

Negative externalities in the form of air and water pollution, noise, danger, visual intrusion, and the like create real costs for society and the individuals who suffer them, even though there may be no apparent expenditures by the victims. An impacted property, for example, may depreciate in real dollars. Equity urges that either increases in negative externalities be mitigated or the recipients be compensated by the purchase of property rights. A transit investment may reduce externalities in some locations (an indirect benefit) and increase them in others. Careful analysis can identify the likely gainers and losers and suggest corrections for any adverse redistributional impacts.

OTHER INDIRECT BENEFITS TO LOCAL COMMUNITY

Running a transit system underground is enormously costly in an urban area, but it results in substantial benefits. One is the saving in land on the surface, which can be put to other uses. This saving is reflected, at least in part, in the lower land cost for constructing the transit line. Another benefit is the amenity to nonusers of having the transportation facility underground and out of sight and hearing. When the residents of Berkeley voted an additional tax on themselves to place part of BART fully underground, they were placing a value on these benefits.

A major transit investment may serve such elusive qualities as neighborhood cohesiveness or civic pride (as BART did during the early stages of construction) or regional image (employers may prefer an area that has a modern rail-transit system). Effects of this sort are not measurable (or are at least unpredictable), and anyway they should show up in other forms if they truly exist.

NEGATIVE IMPACTS

Where it is possible to have positive impacts, it is also possible to have negative impacts. An investment alternative may reduce the housing stock (by direct or indirect demolition of dwellings), increase inflation (by straining limited local labor and capital resources), destroy neighborhoods (through parking demand, station-access congestion, or stimulation of encroaching development), and create visual degradation. BART-related redevelopment of the Mission and Rockridge neighborhoods has been stymied by fears of displacement and incompatible development, and parking demand has generated problems in Daly City. Reduction in noise and air pollution in one location may be offset by increases at other locations. Pressures for higher-intensity mixed land uses will result in conflicts and negative spillovers unless the transition is sensitively handled. Making intelligent choices among alternatives means correcting or minimizing the negative impacts and carefully designing to maximize the positive impacts.

CONCLUSIONS

A range of arguments has been presented for including indirect economic and development impacts in the evaluation of major transit investment alternatives. Suggestions were made for assessing whether each argument was valid in the specific case and for generating the empirical estimates of any benefits that arise from E&D impacts. Most of the rationales offered above are elusive in quality, and quantitative estimates of benefits are likely to be very imprecise (22). Reasonability checks, consistency with regional forecasts, and market analysis will be more helpful than complex quantitative models. We urge that attention be given to the application of sound concepts and appropriate empirical methods rather than to refined analyses of largely unimportant numbers. Revitalization of urban areas, more-efficient patterns of land use, and favorable redistribution of income are potential consequences of transit investment, but these impacts will occur only under nearly ideal conditions. Actions taken on the part of all the levels of government involved in a transit investment will have a greater effect on the outcome than will efforts to predict scientifically the exact impacts of each alternative investment, but careful analysis is still required.

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Lessons from an Economic Analysis of an Intercity Road in a Hypothetical Developing Country

JOHN W. DICKEY

An economic analysis of a proposed intercity road in a developing country is presented. The case is hypothetical, but the data have been selected to be representative of several real-world nations. This analysis extends current efforts by considering pricing adjustments, including inflation, shadow-price premiums, and utility premiums. Results then are judged on the basis of seven economic indicators for three sets of conditions: (a) variations in inputs, (b) inclusion (or exclusion) of different pricing adjustments, and (c) alternative projects. The results lead to lessons for economic analysis, some of which have never been expressed before.

Part of a World Bank project to develop a set of guidelines for highway-project appraisal for training purposes involved creation of a hypothetical case study. This was intended to describe the joint use of many of the procedures currently in practice or proposed for the economic analysis of intercity road projects in developing countries. To my knowledge, these procedures have never been totally employed in any real-world project, so that a sample application, although hypothetical, might prove to have some useful lessons for both technicians and decision makers. It should also be noted that, although the example is hypothetical, the data are considered to be representative of conditions in some developing countries.

HYPOTHETICAL SITUATION

The case study proposed here involves the hypothetical country of Alfredo, which has a population of about 3 million. It is a relatively small country (about 250 km by 250 km). The middle part of the country is mountainous and has elevations up to 2000 m. Because of the elevation, the climate in the central area is moderate; temperatures range from 15° to 26°C. Hence a large proportion of the population has elected to settle in that area, which also is the location of the capital.

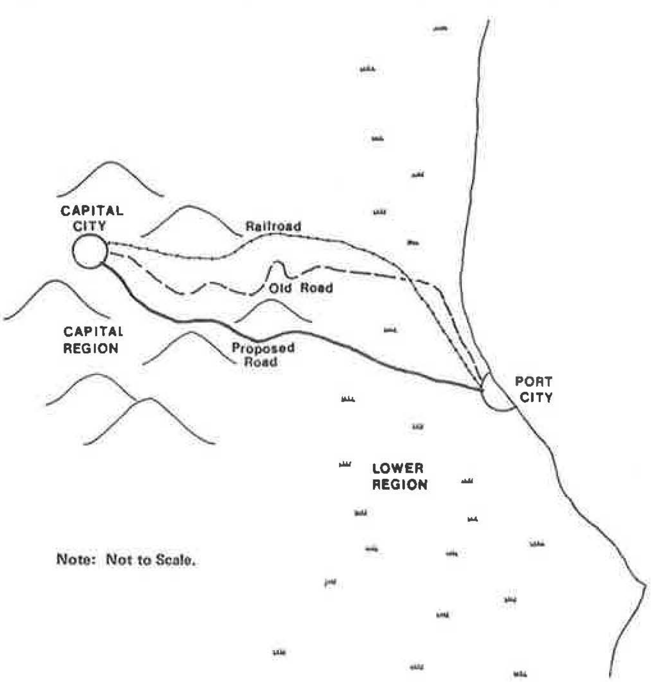
A major ocean port city is located about 100 km to the east of the capital (see Figure 1). The terrain between the two cities can be divided into two parts. The first 50 km from the capital is mountainous, but there is a gentle decline to sea level. The remaining 50 km is essentially flat and has many swamps and marshes. The climate in this comparatively sparsely settled region is tropical; the rainy season lasts about five months. As a result, there is some (although not severe) flooding during that time.

The main redeeming feature of the lower region is that, in those parts in which the soils are suitable (about 30 percent of the region), abundant crops, especially fruits, can be grown. These can be and have been marketed commercially.

Mean per-capita income in Alfredo is about $700 (1975 U.S. dollars). Although the real gross national product (GNP) per capita increased nicely at about 4 percent/year up to 1974, it started to decline and perhaps became negative in 1975. This was due in great measure to large increases in the price of oil imports.

Transportation between the capital and the port is not the best. Through service is provided by the National Railroad Agency, which uses a narrow-gauge line built in the 1860s. It usually takes 7 h to cover the 110-km stretch of line. A slightly longer (120 km), more-circuitous road parallels the rail line most of the way. The road is graveled but has some steep slopes and hazardously sharp horizontal and vertical curves in the mountainous portions. The entire trip by road generally takes 3.5 h by automobile and 4.5 h by the average truck. Portions of the road are closed, however, during most of the rainy season, so it is difficult to make a trip at that time. The railroad is somewhat more reliable in this respect, since it is located on higher ground in the mountainous section.

Figure 1. Alfredo: main transport links between capital and port city.



A new roadway from the capital to the port city has been proposed. It would pass through an area in which many poor farmers now reside and would provide a market connection to the capital and the port. The proposed highway, which would be paved and more direct (only 100 km in length), would cut the city-to-city travel time by automobile from 3.5 to 2.5 h and by truck from 4.5 to 3.5 h.

There is a strong possibility of a Global Lending Bank (GLB) loan to help pay for the capital investment in the road (and also for some maintenance buildings and equipment). The loan would be made and repaid in U.S. dollars at the current interest rate of 7 percent/year, and repayments would start after completion of the highway.

ALTERNATIVES

Although the new road was assumed as a "given" in the analysis, several other complementary actions were possible. First, the GLB loan could be rejected and the project funded entirely by the government of Alfredo. Second, construction could be delayed for various lengths of time. Third, labor-intensive techniques could be employed for both construction and maintenance. Fourth, in conjunction with rural credit programs, loans and grants could be made to enhance vehicle ownership by the poor. These four alternatives were assessed in this study, and in addition sensitivity tests and risk analyses were made on certain inputs (e.g., prices).

ANALYSIS

Several goals and indicators for economic impacts were identified as being important. These are listed in Table 1. The first two impacts are of concern to the user, the third to the government agency that pays for the facility and its maintenance, the next two to the nation as a whole, and the sixth to the poor in the impacted region. An additional indicator, to be described later, is the overall net present utility (NPU) (1).

As a means of analyzing these indicators, those affected by the road were divided into four groups (2):

1. Government of Alfredo (various ministries),
2. Skilled workers (assumed to be the relatively rich),
3. Unskilled workers (assumed to be the relatively poor), and
4. "Foreigners" (those outside the country who were gaining or losing foreign exchange).

The ensuing analysis involved a process that had 11 main steps, as shown below (3-8) [the price unit in Alfredo was called the "numero," symbolized by the number sign (#)].

1. Estimate construction and maintenance costs (current #);
2. Estimate unit user costs (current #);
3. Estimate traffic levels (vehicle miles of travel);
4. Estimate loan costs (current #);
5. Estimate changes in technology;

Table 1. Goals and indicators for selected economic factors.

Impact Factor	Goal	Indicator
High cost of travel	Reduce cost	User costs (time, fuel, maintenance)
Low benefits	Increase benefits	Difference between amount users will pay and amount actually paid
High cost of transport facilities	Reduce cost	Construction and maintenance costs
Lack of foreign exchange	Increase foreign exchange	Net foreign-exchange funds
Lack of investments	Increase savings	Net savings
Low income	Increase income	Per-capita utility of income
Lack of overall value	Increase value	Net present utility

6. Estimate fuel-tax revenue (current #);
7. Estimate discount rate;
8. Estimate rates of inflation;
9. Establish shadow prices (premiums) for (a) skilled labor, (b) unskilled labor, (c) foreign exchange, and (d) savings (as opposed to consumption);
10. Establish utilities of income (premiums) for skilled and unskilled labor; and
11. Estimate economic indicators.

For ease in understanding, the exchange rate at the beginning of 1975 (the first year of the project) was set to be #10 = $1 U.S. The construction period was to be four years (1975-1979) and there was to be a horizon period of 20 years (1980-1999) beyond that.

In the analysis process described above, the first step was to estimate construction and maintenance costs in current numeros. This was a relatively straightforward and common task, as was estimating user costs and traffic levels (steps 2 and 3). In step 4, forecasts were made of principal, interest, and loss of foreign exchange associated with the proposed loan from GLB.

Step 5 involved guessing future vehicle fuel efficiencies as affected by new technologies. Similar rough estimates had to be made for technological changes in maintenance procedures. In fact, both were assumed (in the base case) not to change at all.

Given traffic levels, fuel efficiencies, and tax rates, it was then possible to estimate tax revenues (step 6). All this was done in current numeros. In the next four steps, however, attempts were made to adjust the prices from the previous steps by (a) discounting them according to the time in the future at which they occurred (step 7), (b) estimating inflation rates and subsequently changing current to constant numeros (step 8), (c) establishing shadow prices or opportunity costs for most of the price items (step 9), and (d) determining weights or utilities of the resultant incomes to each group described earlier (step 10). The final outputs (step 11) were scores for each of the seven economic criteria listed in Table 1.

Step 1: Estimate Construction and Maintenance Costs

Construction costs were divided into eight categories (e.g., cut/fill, bridges). Total cost (in current numeros) was estimated at #150 million for the 100-km, two-lane road, or approximately $150 000 U.S./km. Maintenance on the new road was expected to start at #2 million/year in 1980 and continue from #2.8 million/year in 1975 for the old road (which was assumed to be kept in passable condition).

Step 2: Estimate Unit User Costs

Three types of user costs were considered--fuel, time, and vehicle maintenance (9). These were computed for three kinds of vehicles--automobiles, trucks, and trains. Fuel costs for automobiles, for instance, were set to be #0.50/km on the existing road in 1975 based on an average fuel efficiency of 10.63 km/L and a cost of #5.31/L. Because of its improved geometrics, the new road was expected to reduce unit travel costs by 10 percent. In addition, the new road was 20 km shorter than the old one.

Step 3: Estimate Traffic Levels

Distance per trip for both automobiles and trucks was presumed to be reduced from 30 to 20 km by using the new road. This, of course, was associated with the more-direct routes and faster travel times (6,7). Traffic volumes, expressed as average daily traffic (ADT), were set at 1000 for automobiles and 1400 for trucks in 1975; growth was to be at 6 percent annually (regardless of any other conditions). It was felt that 95 percent of traffic on the old road would be diverted to the new and that an additional 20 percent of traffic would be made up of induced traffic.

Step 4: Estimate Loan Costs

The loan from the GLB was assumed to be paid in U.S. dollars; repayment was to be in that same currency. With Alfredo's numeros set to inflate at 13 percent/year and the U.S. dollar at 10 percent (step 8), the exchange rate in numeros per U.S. dollar would increase from 10 in 1975 to 19.07 in 1999. With a GLB loan of #75 million (half the construction cost), Alfredo would have to repay a total of #195.6 million. Of this, #75 million would be the principal; #66.6 million, interest; and about #54 million, loss on foreign exchange because of inflation of the numero relative to the U.S. dollar. Note that the third value almost equals the interest and is more than 70 percent of the principal (5).

Step 5: Estimate Changes in Technology

In the base case no changes were assumed in vehicle-fuel technologies or in road-maintenance procedures. The former may be unrealistic, given recent improvements in engines, but then fuel efficiency is already high in most developing countries.

Step 6: Estimate Fuel-Tax Revenue

Given the fuel-tax rate on a numero-per-liter basis, we can forecast revenue in each year R(t) by using the following equation:

$$R(t) = \sum_{m=1}^{M} \sum_{f=1}^{F} [365A(m,f,t)K(m,f,t)T(t)]/E(m,f,t) \quad (1)$$

where

M = total number of modes,
F = total number of facilities for a given mode,
A(m,f,t) = ADT of mode m on facility f in year t,

K(m,f,t) = mean trip length of mode m on facility f in year t,
T(t) = tax rate (#/L) in year t, and
E(m,f,t) = fuel efficiency (km/L) of mode m on facility f in year t.

Step 7: Estimate Discount Rate

Estimation of the discount rate is always a difficult task. However, since rates of return on many World Bank projects range from 10 to 20 percent, a value of 15 percent was felt to be reasonable (5).

Step 8: Estimate Rate of Inflation

Estimating the rate of inflation was another difficult, yet important, task. Price rises in petroleum assuredly will continue at a high rate, whereas those for, say, aggregate for subbase construction may increase much more slowly. Subsequently, rough estimates of annual charges in percentage per year (presumed constant into the future) were made for each input item, as shown below:

Input Item	Rate (%)
Skilled labor	16
Unskilled labor	12
Machinery	10
Land	17
Petroleum	20
Aggregate	5
Other materials	10
Overall	13

Step 9: Establish Shadow Prices

Four types of shadow prices were set, as indicated in the list above. Skilled laborers, generally considered underpaid in developing countries, were given a premium of +20 percent of their wages. Unskilled laborers, usually overpaid relative to what they would receive in a completely competitive environment, were assigned a premium of -30 percent. Foreign exchange, in great demand, was given a premium of +50 percent (1,4,10).

Since there is a tendency in developing countries to consume rather than to save (invest), a shadow-price premium for savings was needed. According to the United Nations Industrial Development Organization (UNIDO) Guidelines for Project Evaluation (4), this can be estimated from the following equation:

$$SPI = [(1 - RRMPRO)(RRMIPS)]/(SRD - RRMPRO*RRMIPS) \quad (2)$$

where

SPI = shadow price for investments,
RRMPRO = rate of reinvestment of private-sector profits (40 percent),
RRMIPS = annual private-sector return on investment (20 percent), and
SRD = social rate of discount (15 percent).

By using the assumed figures (in parentheses), SPI turns out to be 1.71. Marginal propensities to save were set at 0.20 for skilled labor, 0.05 for unskilled labor, and 0.15 for government workers.

Step 10: Establish Utilities of Income

Establishing utilities of income was perhaps the most difficult task, since it is discussed much but rarely practiced (11). Almost everyone agrees that one unit of money is worth much more to the poor than to the rich. Consequently, we selected a utility premium of +50 percent for each added numero of income to the poor (unskilled labor). For the rich (skilled labor), the utility premium was -50 percent.

Step 11: Estimate Economic Indicators

Based on the preceding estimates, we were able to make forecasts of the seven economic indicators listed in Table 1. The net present utility (NPU) was the sum of the discounted income that accrued to each of the four groups of people combined with the weighting by the utility premiums identified in step 10. To carry out this process, we had to follow these procedures:

1. Take benefits as the consumer surplus under each demand curve (assumed linear),
2. Set the distribution of benefits and costs according to the group affected, and
3. Set the flow of income from one group to the other.

As an illustration of the latter two procedures, it was assumed that skilled labor (the rich) would obtain 100 percent of the benefits to automobile traffic and 70 percent of those to truck traffic, since they are predominantly the owners of such vehicles. Still, in the case of trucks, they must transfer some of these benefits to hired drivers (unskilled labor) in the form of wages and all the fuel-tax payments to government. Similarly, government must transfer money to both skilled and unskilled labor for payment for road construction and maintenance.

RESULTS OF ANALYSIS

Several sets of runs were made by using the analysis procedures described above. These runs were divided into three classes:

1. Sensitivity tests on inputs,
2. Inclusion (or exclusion) of various pricing adjustments (steps 7-10 above), and
3. Tests of project alternatives.

The results of these runs are presented in Table 2.

Base Case

If the decision were made to implement the project as initially proposed, it would appear to be highly advantageous as opposed to the "do-nothing" alternative (Table 2, base case). User travel costs would be reduced #1318 million, whereas the corresponding benefits would increase #892 million over the lifetime of the project. Relative foreign-exchange gains would be a wholesome #892 million (however, as it turns out, actual foreign-exchange deficits would continue to mount, although not so quickly). Investments by government and the public at large would rise by about #486 million, and the poor in the region would have their net incomes increased by #749 million. NPU would increase by 400 million utiles. The only economic indicator that showed a relative disadvantage was cost, since the new project obviously was going to entail additional expenditures.

Sensitivity to Inputs

Four tests were made on the sensitivity of the base-case results to changes in various inputs. In the first, the social discount rate (always difficult to establish) was assumed to be 25 percent rather than 15 percent as in the base case. None of

Table 2. Results of runs for variations in inputs, various pricing adjustments, and alternative projects.

Variable	Economic Indicator: User Costs (# 000 000s)	User Benefits (# 000 000s)	Project Costs (# 000 000s)	Available Foreign Exchange (#)	Investments (# 000 000s)	Income to Poor (# 000 000s)	NPU (millions of utiles)
Tests on Inputs							
Base case	1318	2024	175	892	486	749	400
Social discount rate, 25 percent	1318	2024	175	892	486	749	145
Traffic growth—4 percent automobiles, 5 percent trucks	1092	1450	175	737	359	600	334
Fuel efficiency—4 percent automobiles, 2 percent trucks	979	1886	175	611	410	666	332
Diverted trips, 90 percent; induced trips, 10 percent	1528	−164	175	1027	149	233	248
Pricing Adjustment							
A	1318	2042	175	892	486	749	400
B	709	1721	190	388	353	677	287
C	709	1721	190	388	353	677	191
D	1318	2042	175	892	486	749	477
E	1318	2042	175	892	486	749	365
F	1318	2042	175	892	486	749	565
Tests of Alternative Projects							
No base	1318	2042	175	892	486	749	400
GLB loan	1318	2042	191	878	483	749	330
Delay project	3162	4878	280	2212	1175	1738	561
Use labor-intensive techniques	1318	2042	192	906	483	790	427
Enhance vehicle ownership	1318	2042	175	892	374	1494	433

Notes: Monetary figures are in constant (mid-1975) numeros but are not discounted.
Pricing adjustments are as follows: A = inflation, shadow-price premiums (SPPs), and utility premiums (UPs); B = no inflation, no SPPs, and no UPs; C = no inflation but with SPPs and UPs; D = inflation, no SPPs or UPs; E = inflation, no SPPs, but with UPs; and F = inflation, SPPs, but no UPs.

the first six indicators changed, since they are reported in undiscounted form. NPU, however, dropped to 145 million utiles. Still, this indicates that the rate of return is more than 25 percent, which is acceptable in most circumstances.

Another trial involved lowering annual traffic growth rates from the estimated 6 percent for all traffic to 4 percent for automobiles and 5 percent for trucks. As can be seen in Table 2, this results in lowering most of the indicators by 20-30 percent. NPU is cut by about the same proportion, from 400 to 334 million utiles. These indices thus would seem to be marginally sensitive to traffic growth rates.

Another sensitivity test was conducted on vehicle fuel-use technologies. It had been assumed for the base case that engine efficiencies would not change over the life of the project. If (as might be the case) the kilometers per liter of automobiles were to increase 4 percent/year and that for trucks 2 percent, the consequence would be a reduction of NPU to 332. This occurs because reducing fuel consumption (and thus costs) through more-efficient engines leaves less room for user cost reductions through better roads, thus the lower NPU. Note, however, that available foreign exchange is less than if traffic were reduced, yet investments and income for the poor are higher.

A fourth sensitivity test involved alternating the percentage of trips diverted from the old road from 95 percent to 90 percent and lowering the percentage of induced trips from 20 percent to 10 percent. These two changes (but particularly the latter) actually made user benefits negative and reduced the NPU to 248 million utiles. (This result seems inconsistent but is in fact possible if construction and maintenance wages, for instance, flow to the poor.) This great change was disturbing because the figure for induced traffic is difficult to estimate and, based on other experiences, conceivably could be only 10 percent.

Inclusion of Price Adjustments

The second series of tests focused on the inclusion of various pricing adjustments in the analysis. What would happen if inflation were not considered (it rarely is in practice), if shadow-price premiums (SPP) were set to zero, and if utility premiums (UP) were not included (there are almost no examples in which they are)? In general, concern is for the veracity of the majority of current economic evaluation efforts, which do not take into account any of these price adjustments.

Row A under Various Pricing Adjustments in Table 2 is in fact the base case, in which all price adjustments are employed. We assume (grandly) that this is the way economic evaluation really ought to be done and that the established adjustment figures are correct. If no adjustments are made (row B), NPU is underestimated by more than 25 percent. Further, user costs and available foreign exchange are about one-half of their "real" value. Interestingly, if the inflation adjustment alone was left out (row C), NPU would be underestimated by more than 50 percent.

The remaining results in this section of Table 2 indicate that if SPPs alone are left out (row E), NPU is underestimated by about 10 percent. If only UPs are set to zero (row F), NPU is significantly overvalued. Finally, if both are ignored (row D), NPU is inflated by about 20 percent.

Project Alternatives

The results relevant to the four alternatives discussed earlier are displayed in the last section of Table 2. If advantage were not taken of the GLB loan, NPU would drop about one-fifth. The reason for this is that the loan provides an opportunity to defer the cost of part of the project to a later date. So, despite the increased costs (interest) and the high weighting given to the resultant additional loss in foreign exchange (down from #892 million to #878 million), the discounting over time would turn out to be a factor of much more consequence.

If the project were delayed four years, benefits would increase even more than costs (when discounted), so that all measures of overall economic viability (except project cost) would improve in comparison with the alternative of immediate construction. This appears to result from the fact that traffic volumes as well as user costs are rising even faster than project costs, so that benefits from reduction in travel cost increase more rapidly.

The labor-intensive construction alternative (8,12,13) led to some interesting results. Because of the anticipated higher construction costs (#228.8 million compared with #206.1 million), NPU would tend to drop somewhat. Yet because of the favorable impact on foreign exchange (less machinery needed) and on the income to the poor, the final NPU would rise to 427 million utiles. The impact from the alternative (14) to enhance vehicle ownership by the poor almost doubled the net income to the poor and raised NPU slightly more than the labor-intensive construction options did.

Lessons Learned

The preceding example, although hypothetical and not representative of conditions in many developing countries, still provides insights into the use of economic analysis in assessing intercity roads in some nations. Many of these lessons are not new, but they bear repeating in the context of a much broader example than has previously been employed. In reviewing these lessons, we must remember that they all are in comparison with the "do-nothing" situation.

1. NPU is, as expected, highly sensitive to the value selected for the discount rate. The selection problem is even more complicated here, however, because we are dealing with a social discount rate (which depreciates future utiles, not monetary benefits) rather than a more-explicit financial discount rate.
2. Fuel-efficiency gains reduce NPU as well as income to the poor and available foreign exchange. Decreased traffic growth also can do this but with less negative impact on foreign exchange and more on income to the poor.
3. Relatively slight changes in the proportions of diverted and induced traffic can have substantial effects on NPU and other economic indicators. This is particularly troublesome given the difficulty of establishing values for the former.
4. Neglecting pricing adjustments will lead to underestimation of most economic indicators.
5. Neglecting inflation alone can lead to substantial underestimation of the economic value of a project.
6. Neglecting SPPs alone has relatively little effect, but this is not so for UPs alone. Together they tend to cancel any effect, but far from completely.
7. Rejecting a partial loan on favorable terms from an international development finance agency will decrease NPU. Still, it should be noted that a major cost of a loan (usually not considered) is a loss in foreign exchange due to variations in exchange rates.
8. Delaying a project increases its value (assuming that traffic volume will continue to increase regardless).
9. A more labor-intensive construction project will increase its NPU, available foreign exchange, and income to the poor slightly.
10. Creating increased vehicle ownership among the poor will substantially improve their income, but NPU will rise about as much as for the labor-intensive project.

These lessons naturally cannot be proved with any certainty, but they should provide the basis for continuing analysis and debate, much of which could not take place in a systematic context without the kind of case study presented here.

ACKNOWLEDGMENT

I would like to thank the World Bank for supporting the training grant under which this study was prepared. Special thanks go to Leon Miller for his close supervision and assistance in the work.

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System-Dynamics Approach to Transportation Planning in Developing Regions

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Transportation is not merely a derived demand but a determinant of new production possibilities. To plan successfully for the development of a region, one must understand the possible causal relationships, feedbacks, and interactions among the different sectors of the region, including the transportation sector. In this study the impacts of three investment strategies for the Essequibo coastal region in Guyana are evaluated by using a computer simulation and system-dynamics methodology. The model consists of three main sectors: demographic, economic (primarily rice production and processing), and transportation. The hypothesized intersectoral relationships were first developed through causal diagrams, which were divided into submodels. Second, the submodels were synthesized to form a comprehensive system-dynamics model represented by approximately 230 equations to evaluate three investment strategies: (a) do nothing, (b) invest in roads only, and (c) invest both in roads and in drainage and irrigation. Sensitivity analyses were performed on the key socioeconomic variables to determine which variables most significantly influence regional behavior. The investment both in roads and in drainage and irrigation provided the greatest net benefit and the most favorable socioeconomic characteristics in terms of population level, regional income per capita, out-migration, and unemployment. Thus, given its financial feasibility, this strategy is recommended.

Transportation in terms of economic development is essentially a derived demand and is dependent on the plans and objectives of the other sectors of the economy. Thus, the correct task of transportation planning may be stated as the accomplishment of all necessary movements at a minimum overall cost to the economy.

However, transportation, once implemented, has a significant influence on the demographic and economic sectors of a region (i.e., it tends to regulate or determine the market mechanism and hence the eventual growth rate and specialization of a region). Transportation is therefore not merely a derived demand but a determinant of new production possibilities (1).

In developing countries, this concept of transportation as a determinant of new production possibilities and demographic change is no longer debated but accepted. The search over the past 20 years has been for "more appropriate" methodologies to evaluate the catalytic effects of transportation investments in already identified, resource-endowed regions in order to determine the priority of limited funds, skills, and equipment in less-developed countries (LDCs).

NEED FOR COMPREHENSIVE AND COORDINATED PLANNING

The premise of transportation planning has been that travel demand is repetitive and predictable and that the transportation system should be designed to meet this future demand. Almost invariably, the planning approach has been to solve capacity deficiencies with emphasis on short-term solutions and without due consideration of the long-term problems that might result from such solutions. It is believed that any planning effort focusing on components and not on the total system will more than likely deviate from the designed national goals and objectives. In addition, the very nature of the transport investment (i.e., high costs and difficult transferability) requires a systems approach if unwanted impacts are to be minimized and resource use maximized.

Each year at least 20 percent or as much as 40 percent of the budgets of LDCs is spent on transportation or transportation-related projects. There is a sincere belief that transportation is an obvious prerequisite to increased productivity and national integration. What is also important is that this trend is more than likely to continue in the foreseeable future.

In resource-scarce economies, ill-advised allocation of national funds in transportation can seriously affect the growth of other sectors of the economy, for example, housing, education, and health. Thus, it is absolutely necessary to ensure that the nation does in fact receive the maximum possible benefit from investments in transportation. From another point of view, international organizations and foreign governments are generally involved in the financing of major transportation projects, and these agencies require assurances (through feasibility studies) of the economic viability of the projects before their loans are approved.

Besides the financial constraints, compartmentalization of planning is also a problem. In LDCs, although intermodal transfers are often required before products reach their final destinations, unimodal planning is usually performed and only provides a partial solution to the mobility of resources.

Because a road, a rail, or a shipping route is built to stimulate economic growth, the appropriate basis of measuring benefits would seem to be the increases in production and services instead of rate of traffic flow per day. Thus, accompanying investments must also be considered, since a road or other transport facility by itself is not sufficient to increase production. In this view, the value of output and input that is possibly attributed to the road alone may no longer be of primary interest. Therefore, the overriding interest is the increase in total output (together with the accomplishment of other goals) that can be attributed to the integrated set of investments. Under these circumstances, the reason for estimating traffic volume is to determine what type of facility should be provided (2).

The direct and induced impacts of transportation investments imply a data base that involves disciplines other than transportation. Unfortunately, in LDCs, not only is the data base lacking but very often whatever little exists may not be usable. The comprehensive and coordinated planning approach may specifically indicate the above needs.

OBJECTIVES OF STUDY

Since the causal and catalytic impacts of transportation and accompanying investments on the region's production and on the shifts in population are important in determining the long-term benefits, a useful planning methodology must be sensitive and responsive to these impacts. To achieve this purpose, the following objectives of the study were formulated:

1. To develop a computer-simulation model by using the methodology of system dynamics to evaluate the socioeconomic impacts of transport and related investments on the regional economy under various policy scenarios and
2. To use the model to identify an appropriate data base for comprehensive and coordinated transportation planning.

SCOPE OF STUDY

This study concerns the analysis of a single region in Guyana, the Essequibo coastal region between the Pomeroon and Supenaam Rivers, a sparsely populated rice-producing region not exploited to its optimal agricultural potential due to inadequate economic infrastructure. The intent is to evaluate the socioeconomic impacts of the following policies: (a) the continuation of the status quo, that is, maintenance of the current facilities and sporadic infusion of small sums of developmental funds (which is the case in most LDCs); (b) investment in transportation; (c) investment in drainage and irrigation; and (d) extensive sensitivity analyses to determine which variables "drive" the model in order to identify a more appropriate data base for future model building and planning.

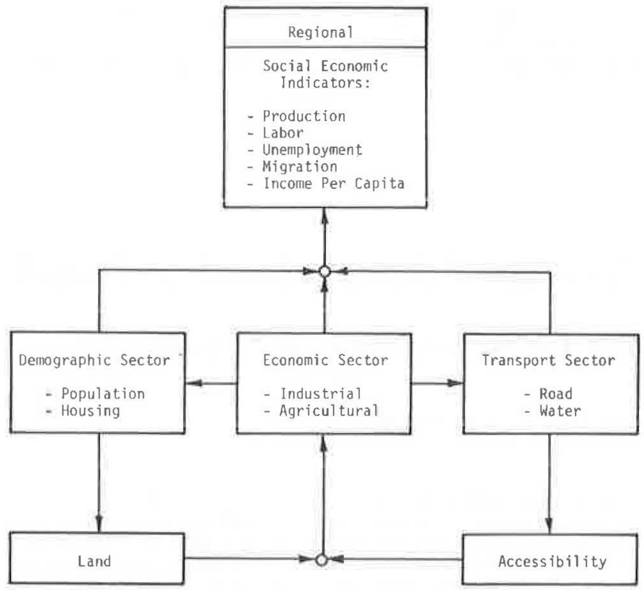
MODEL FORMULATION

The hypothesis of the model formulation is that there are significant intrasectoral and intersectoral linkages and feedbacks among the variables that express the behavior of the economy at any time. Decision in any one of the sectors will eventually affect the other sectors. The effects may appear immediately or over a prolonged period of time. This feedback or cause-and-effect phenomenon exists and can be depicted in a simplified diagram, as shown in Figure 1. This diagram shows that, if nothing else, land availability will eventually constrain the growth of the region, which makes the spatial distribution of activities in the demographic and economic sectors more dependent on the level of accessibility provided by the transportation sector.

In the following sections, the model is presented in more detail so that the causal relationships among the system elements can be understood. The dynamic structure of the model is illustrated by using a system-dynamic presentation, since it is more convenient to show the direction and the polarity of impacts among the variables.

According to the theory of system dynamics, the relationship between two variables is positive if

Figure 1. Flows between major sectors of region.



both of them vary in the same direction; otherwise, it is negative. Usually a dynamic model is composed of many causal relationships, which often close on themselves to form feedback loops. The significance of a feedback loop is in the behavior that the system exhibits. There are basically two types of behavioral patterns that are of interest in a qualitative analysis--explosive and asymptotic. The explosive growth pattern is characterized by positive-feedback structures, whereas the asymptotic growth pattern is normally seen from negative-feedback structures. Detailed information on system dynamics has been given by Goodman (3).

The regional economy to be modeled in this study has three interdependent sectors: (a) the demographic sector, which consists of the population and the housing components; (b) the economic sector, which includes a rice-producing component and a rice-processing component; and (c) the transportation sector, which is made up of two modes--road and water. The influences (positive and negative) and the directions of the impacts are first presented in the form of causal diagrams, which are organized according to the submodels of the main sectors. The mathematical difference equations for these causal relationships are then derived. Second, the causal submodels are linked together (synthesized) to form a comprehensive model of the economy. Finally, the comprehensive system-dynamic model is simulated for different policy scenarios.

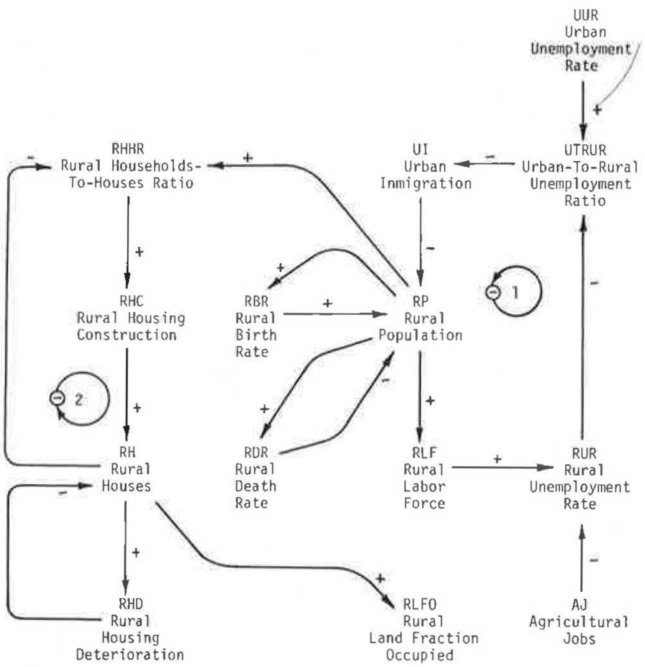
The focus of the model's design is to evaluate investments--mainly in transportation and in drainage and irrigation--at both the tactical and strategic levels through the following socioeconomic indicators: regional rice production, gross regional production, gross regional income per capita, regional population, regional unemployment, regional jobs, regional migration, and net present value of investments. The sectors and their main components discussed below are explicitly represented in the model.

Demographic Sector

The demographic sector is represented by the population and the housing components. The regional population level determines the labor force, unemployment, and income per capita of the region and exerts a strong influence on the housing component and conversion of land use from agricultural production to housing. The rate of growth of this sector is determined by the birth, death, and migration rates of the region. Figure 2 shows that the demographic sector has two main negative-feedback loops underlying its dynamic structure: a population-movement loop (labeled 1 in Figure 2) and a housing-construction loop (labeled 2). Loop 1 shows that population movement is governed by the relative unemployment rates between the rural region and the urban center (i.e., the nation's capital). On the other hand, loop 2, the housing-construction loop, is constrained by the housing demand exerted by the increased rural population.

The regional population at any time t is equal to its previous value at time (t - 1) plus the total births minus the total deaths and the number of people migrated to the urban center. The region's birth rate and death rate are based on historically observed trends, whereas the urban in-migration rate is assumed to be dependent on the job opportunities of the rural region and the urban center. As the ratio of urban unemployment rate (UUR) to rural unemployment rate (RUR) decreases, people will leave the rural region.

Figure 2. Causal relationships within demographic sector.



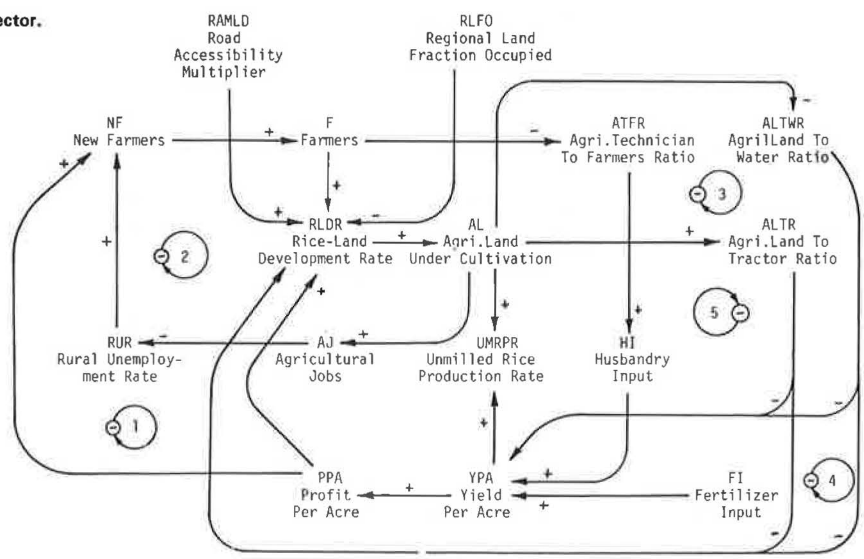
Economic Sector

Causal Relationships

Agricultural production and productivity are dependent on the following main factors: the available arable land area, the number of farmers, mechanization, drainage and irrigation (i.e., water supply), fertilization, technical advice (i.e., extension services to farmers), profitability of farming, and the cost and level of accessibility of transportation. The rate of growth of this sector is influenced by the rate at which available arable land is brought under cultivation, whereas the land area under cultivation determines the socioeconomic performance of the region through such variables as number of jobs and production rate. Figure 3 shows that the agricultural portion of the economic sector is driven by five negative-feedback loops. Loop 1 [farmers, ratio of agricultural technicians to farmers, husbandry input (HI), yield per acre, profit per acre, and new farmers] shows that extension services (HI) have a positive impact on yield, profitability, and new farmers. This is a negative-feedback loop because as the number of farmers increases, the ratio of agricultural technicians to farmers decreases and, in turn, negatively affects HI.

Loop 2 (farmers, land-development rate, agricultural land, jobs, unemployment, and new farmers) shows the impacts of agricultural land under cultivation on jobs, unemployment, and the number of people who turn to farming. Figure 3 also shows that the rural-land-development rate (RLDR) is influenced by six key variables: accessibility, farmers, rural land fraction occupied, ratio of agricultural land to tractors (mechanization), ratio of agricultural land to water (drainage and irrigation availability), and profit per acre (profitability). Also, the yield per acre is a function of fertilizer input, HI, mechanization, and drainage and irrigation.

Figure 3. Causal relationships within economic sector.



Mathematical Relationships

The agricultural part of the economic sector of the model computes the number of farmers, land-development rate, rice-production level, yield per acre, acreage under cultivation, and job level, among other variables. The equations for the three dominant variables are presented below.

Rice-Land-Development Rate

The land-development process is assumed to be affected by the availability of agricultural infrastructure (e.g., drainage and irrigation, roads, and cultivatable land). The acreage developed for rice farming is assumed to be as follows:

$$RLDR_{t+1} = \max[RLDM_t \times RLA \times RAMLD_t \times (1 - RLFO_t),0]/DILD \quad (1)$$

where

$RLDR_{t+1}$ = rice-land-development rate (acres/year) at time t + 1,
$RLDM_t$ = rice-land-development multiplier at time t (dimensionless),
RLA = regional land area under consideration,
$RAMLD_t$ = road-accessibility multiplier (index) at time t,
$RLFO_t$ = regional land fraction occupied at time t, and
DILD = delay in land development.

RLDM is assumed to be a function of drainage and irrigation, profitability from farming, available arable land, farmer availability, and mechanization.

Yield per Acre

The amount of rice yield per acre (YPA) is the product of the normal YPA (YPAN) and a set of multipliers that represent the human and the technological inputs. YPAN is the minimum yield without fertilizer, guaranteed drainage and irrigation, mechanization, and extension services from agricultural technicians. The equation is written as follows:

$$YPA_t = YPAN \times FEAM_t \times DIAM_t \times MIM_t \times HM_t \quad (2)$$

where

YPA_t = YPA (tons) at time t,
YPAN = normal yield (constant),
$FEAM_t$ = fertilizer-availability multiplier at time t,
$DIAM_t$ = drainage and irrigation multiplier at time t,
MIM_t = machinery-input multiplier at time t, and
HM_t = husbandry multiplier at time t.

DIAM is assumed to be a function of the ratio of irrigation water demand to supply. MIM is a function of the ratio of farm equipment to farmland. HM represents the farming skill and advice that farmers could get from agricultural technicians and is assumed to be a function of the ratio of agricultural technicians to farmers. Finally, FEAM is a function of pounds of fertilizer available per acre of rice-farming land.

Unmilled-Rice-Production Rate

Because the supply capacity of the irrigation system is limited, the production of unmilled rice is considered by using two cases. In the first case, if the rice land under cultivation is less than the maximum acreage (RL1) that can be accommodated by the irrigation system, the production of rice is as follows:

$$UMRPR_{t+1} = YPA1_t \times RL_t \quad (3)$$

where

$UMRPR_{t+1}$ = unmilled-rice-production rate (tons/year) for region at time t + 1,
$YPA1_t$ = YPA at time t under sufficient water supply (tons/year/acre), and
RL_t = rice land under cultivation at time t.

For the case in which the amount of land under cultivation exceeds the maximum acreage determined by the irrigation system, the total rice produced is shown as follows:

$$UMRPR_{t+1} = YPA1_t \times RL1 + YPA2_t \times (RL_t - RL1) \quad (4)$$

where RL1 is the maximum acreage of land that the irrigation system can accommodate and $YPA2_t$ is YPA at time t under insufficient water supply; YPA2 is less than YPA1.

These two cases take into account the situation in which the production of rice is predominantly determined by the availability of water instead of by other factors.

Transportation Sector

The transportation sector, which is the primary focus of the model's design, is represented by two modes--road and water; the dominant emphasis is on the road. In this scenario, road accessibility is perceived to be the primary constant to the rate of land development, and water transportation is incorporated so that the desired water-transport capacity keeps pace with the regional production level. The sector is explicitly represented by the following main components: road funds (construction and maintenance), total miles of road, effective miles of road, desired road density, accessibility, and transport capacity. Figure 4 shows that this sector is composed of four main feedback loops. Loop 1 (transport capacity, unmilled-rice-transport rate, agricultural-production rate, desired number of trucks, truck-purchase rate, and number of trucks) shows the impact of transport capacity on the amount of produce that actually reaches the market. The positive polarity, or increasing-impact loop, quite clearly indicates that transport availability positively influences production rate. Furthermore, capacity depends on both the mobile stock (trucks) and the accessibility to the farms.

Loop 2 (rural road miles, effective road miles, transport capacity, unmilled-rice-transport rate, unmilled-rice-production rate, truck trips, and road-deterioration rate) shows that increased agricultural production requires more truck trips, which causes a higher road-deterioration rate; so fewer effective road miles remained. A drop in effective road miles decreases transport capacity and hence negatively affects the agricultural-production rate. The influence on agricultural production represents the response of farmers to spoilage of crops due to their inability to transport crops to the market.

Loop 3 (road-accessibility multiplier, agricultural-land-development rate, unmilled-rice-production rate, truck trips, road-deterioration rate, and road miles) shows that accessibility positively influences land-development rate. In loop 4, the

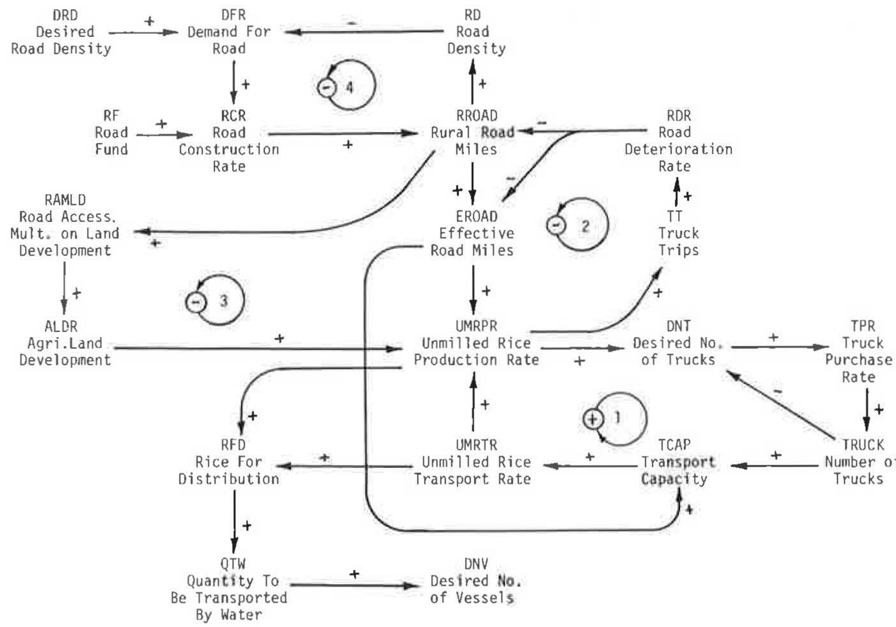


Figure 4. Causal relationships within transportation sector.

road-construction mechanism is represented as controlled by the desired road density. It is evident that there must be a required level of road miles in the region to allow for a maximum farm cultivation and productivity. This level of road miles is achieved in the model through density of road required for rice cultivation.

Mathematical Relationships

The transportation sector of the model computes the level of road miles, the expenditures on construction and maintenance, the after-production loss due to inadequate transport capacity, the road-accessibility multiplier, and the desired number of trucks and ships needed to match the production level. The following main equations of the sector are presented.

Road-Construction Rate

The rate of new road construction in the region is assumed to be influenced by the demand for roads and the available funds allocated for new construction. This demand is further influenced by the availability of farmers and land for new road construction. The equation is as follows:

$$RCR_{t+1} = \min\left[DFR_t(RCB_t/CCPM) \times IFFM_t \times RRLAM_t\right]/RCT \quad (5)$$

where

- RCR_{t+1} = road-construction rate (miles/year) at time t + 1;
- DFR_t = demand for roads at time t;
- RCB_t = road construction budget at time t;
- CCPM = construction cost per (representative) mile of road in network;
- $IFFM_t$ = dimensionless variable that represents influence of farmers on road-construction rate at time t;
- $RRLAM_t$ = rural-road-land-availability multiplier, which represents availability of land for road construction at time t; and
- RCT = road-construction-delay time (time required for road construction from planning to operation).

The demand for roads is a function of the ratio of actual road density to the desired road density for the crop type under consideration.

Road-Transport Capacity

The road-transport capacity is assumed to be dependent on the characteristics of the road network, the number of trucks available to the rice industry, and the short period over which the entire product must be harvested. The equation is as follows:

$$RTC_t = TRUCK_t \times TTPD_t \times HPP \times PLPT \quad (6)$$

where

- RTC_t = road-transport capacity (tons) at time t,
- $TRUCK_t$ = number of trucks available at time t,
- $TTPD_t$ = truck trips/day,
- HPP = harvesting-peak period, and
- PLPT = payload/truck.

SYNTHESIS OF SECTOR MODELS

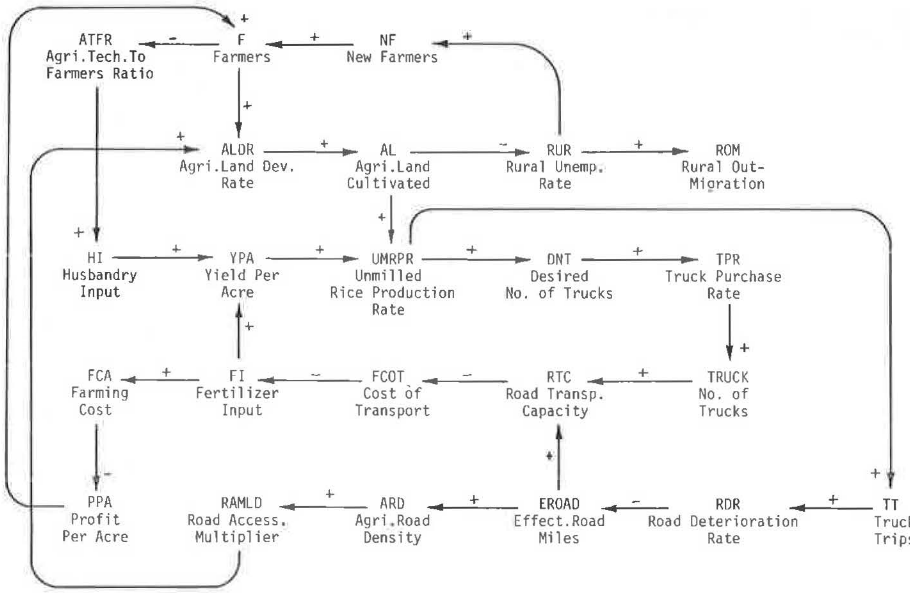
Figure 5 shows the simplified causal diagram of the coupling of the three sectors. The important intersectoral impacts are recognized through the following variables: urban in-migration, unmilled-rice-production rate, cost of transport, and the agricultural-land-development rate. The comprehensive mathematical model is defined by approximately 230 equations.

BRIEF DESCRIPTION OF REGION

The area of influence lies between the Pomeroon and Supenaam Rivers on the Essequibo coastal area of Guyana. The arable area is defined by the Atlantic Ocean on the north, the Pomeroon River on the west, the Supenaam River on the east, and the interface between the clay strip (arable soil) and the "pegasse" (an organic loamlike, subarable material) on the south. This southern boundary is between 1 and 5 miles from the Atlantic Ocean and defines the potential arable land region of 60 000 acres.

The current population is estimated at 35 000 and

Figure 5. Simplified causal structure of agricultural economy.



lives within a half mile from the Atlantic Ocean. The area is drained by minor rivers and by an extensive drainage and irrigation scheme, the Tapakuma Scheme, which is now capable of irrigating 30 000 acres effectively.

The prime economic activity is growing and processing rice. An estimated 29 000 tons of rice are produced on the currently cultivated 30 000 acres of the potentially feasible area of 60 000 acres. At an average price of G$450 (Guyanese dollars)/ton, the base component of the gross regional product is of the order of G$13 050 000.

The area is accessible to Georgetown by means of water transportation. There is also a light-aircraft airstrip in the region. On the coast itself, road is the only means of travel between the communities. There is a coastal road that connects Pomeroon and Supenaam, which are approximately 40 miles apart. Of the 40 miles, 16 miles can be considered paved, and the remainder poor in all weather. There are also approximately 110 miles of dirt farm roads that become impassable in the wet season and seriously affect the rice production and productivity.

DESCRIPTION OF POLICIES TESTED

Do Nothing (Base Case)

Allocation of funds to the region in the recent past has been approximately G$1 000 000/year for both reconstruction and/or improvement of the existing road network and maintenance. The policy's emphasis was to push, or to expand the road mileage to the extent that the funds would allow. That is, there was a tacit agreement to neglect adequate maintenance of existing roads, which resulted in sections that were impassable in the wet season.

Fund Road Development

The desired network for the region is dictated by the cultivation of rice, which requires approximately 2.5 miles of all-weather road, 2.5 miles of dirt road, and 0.5 mile of paved collector road for every 1000 acres to be brought under cultivation. A composite-mile cost is estimated to be G$100 000/mile for construction and G$1000/mile for maintenance.

Fund Both Roads and Drainage and Irrigation

Under the scenario that funds both roads and drainage and irrigation, it is recognized that drainage and irrigation are absolutely necessary if the benefits of investments in other types of farm inputs are to be maximized. Currently, the region has a water supply adequate for 30 000 acres, and it is estimated that another G$20 000 000 are required to provide adequate drainage and irrigation for the remaining 30 000 acres. The investment in drainage and irrigation is represented in the model by removing the water constraint on production.

ANALYSES OF OUTPUTS FOR POLICIES TESTED

Under the do-nothing policy, the desired level of road miles will not be reached for 30 years. The acreage brought under cultivation increases very slowly, almost negligibly for the first 12 years, and then moves rapidly after the impact of the road input is provided. The region continues to lose population for the first 16 years, and then the trend is reversed after the acreage under cultivation has been significantly increased from 30 000 to 44 600 acres. Production, as expected, follows the land-growth characteristics. The behavior of the region stabilizes after about 30 years.

Under the second policy, investment only in roads has a dramatic impact on the acreage brought under cultivation, unemployment, out-migration, and population. The desired road network will be completed in five years, and land under cultivation reaches 47 900 acres from the initial 30 000 acres. Out-migration from the rural region is reversed after the third year of the investment from an initial value of 1400 persons leaving to 549 persons coming into the region. Paddy (unmilled-rice) production jumps from 47 700 to 71 400 tons in five years. Equilibrium behavior is reached within 17 years at a production level of 74 400 tons of paddy/crop.

Finally, the comprehensive investment strategy, which includes both the roads and drainage and irrigation, results in the greatest impact within the shortest time span. Rice land cultivated within five years reached 50 000 acres from the initial 30 000 acres. Regional migration is reversed from a high of 1400 persons out-migrating to 740 in-migrating, and this trend continues to the seventh year.

Table 1. Results of economic analysis of three policies tested.

Strategy	Present Worth (G$) Costs (G$) Roads	Drainage and Irrigation	Benefits	Net Present Worth (G$)	Benefit/Cost Ratio
Do nothing	11 385 840	-	20 243 350	8 857 510	1.77
Invest in roads	20 863 850	-	36 815 090	15 951 240	1.76
Invest in roads and in drainage and irrigation	20 863 850	20 000 000	50 766 560	9 902 710 19 805 420[a]	1.20 2.40[a]

[a]Given guaranteed drainage and irrigation, double cropping per year will result in increased benefits.

Table 2. Steady-state values for main socioeconomic indicators.

Economic Indicator	Strategy: Do Nothing	Invest in Roads	Invest in Roads and in Drainage and Irrigation
Rice land cultivated (acres)	51 600	53 400	53 800
Paddy production (tons/year)	71 400	74 500	99 128
Gross regional product (G$)	14 280 000	14 900 000	19 826 000
Net regional product (G$)	4 076 000	4 566 000	6 402 000
Gross regional income per capita (G$)	318	317	413
Road miles	325	330	330
Population (thousands)	44.9	47	48
Unemployment (%)	20	22	22
Jobs	14 000	16 700	16 800
Out-migration (persons/year)	460	1050	1050
Equilibrium time (years)	30	17	15

Production jumps from the initial level of 47 000 tons to 86 000 tons/crop, and with a guaranteed water supply, there is every likelihood that double cropping per year will be undertaken, which results in twice the output per year. Equilibrium values for all the main socioeconomic variables are reached within 15 years.

Table 1 gives the results of the analysis of the impacts of the three investment strategies based on a 20-year simulation at 10 percent annual interest rate and one crop per year. The traditional net-present-worth and benefit/cost-ratio techniques were used to evaluate the impacts. However, what impacts per year (values of output per policy) are discounted to present values makes a significant difference. The traditional approach, or horizon-year planning, would have discounted average forecast values for, say, 5, 10, 20, or 30 years to present worth at the specified interest rate. The system-dynamics technique used in this study provided the impacts (outputs) for every year of the simulation. The dynamic nature of the feedback phenomenon throughout the transient stage requires that the annual behavior or output be evaluated instead of point projections to the horizon year.

Table 2 gives the outputs of the behavior of the model at equilibrium for the three policies. Questions concerning the levels of employment, migration, and regional income per capita are often asked by decision makers before the allocation of scarce resources is finalized. The model explicitly provides a trace through time of the behavior of these main socioeconomic variables and thus answers the questions concerning the social impacts of the investments.

CONCLUSIONS

The model explicitly shows the impacts of the different investment strategies in a cause-and-effect manner. Moreover, the reasonableness of the results obtained from the simulation runs suggests that dynamic-feedback system models can be developed and used to evaluate the effectiveness of different resource-allocation policies.

The trace of the behavior of the main socioeconomic variables through time provides for a more valid evaluation of the costs and benefits of a given investment than the traditional horizon-year forecast. The knowledge of the transient behavior is necessary in decision making and can be sufficiently illustrated by a closer examination of the model's output. Table 2, for example, shows that at equilibrium there are indeed very few differences among the three policies in terms of final behavior. The do-nothing alternative is even better in terms of unemployment and out-migration (20 percent and 46 persons, respectively) compared with the other two policies (22 percent and 1050 persons). Thus, given a horizon of 30 years, one is likely to choose the do-nothing scenario, since it is the least costly and has the highest benefit/cost ratio--1.77. However, the dynamic behavior through the transient state and the analysis of present-worth values, as given in Table 1, would completely reverse the preference for the do-nothing policy. This is because the other two policies reach their potential in less than half the time of the do-nothing policy and with less adverse unemployment and out-migration impacts.

The model may be challenged on the basis of the hypotheses and the functional relationships of the variables. However, these limitations represent areas of analyses, which, if undertaken, should improve rather than alter the basic results of the model.

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Cross-Impact Analysis of Proposed Railway System

FAZIL T. NAJAFI

Developmental impacts of a proposed railway system that extends from Karachi, on the Persian Gulf, and goes through Pakistan, Iran, and Afghanistan (the PIA region) to Rasht, on the Caspian Sea, were analyzed and their projected occurrences were measured by a forecasting method called the cross-impact technique (CIT). The Karachi-Rasht Railway (KRR) impacts were identified through (a) an analogous link, the Suez Canal; (b) the study of the socio-economic characteristics of the PIA region; and (c) the international railways of East Africa and western Europe. These facts helped provide comparative data for estimating the future levels of such aspects as energy consumption, food production, life expectancy, literacy rate, per-capita income, etc., relevant to the impact of KRR. As a first step in CIT, relationships among the 25 developmental events were established and an initial probability and an occurrence date were assigned to each event. CIT takes into account the interaction among the events by using a FORTRAN program to generate the likelihood of occurrence of each event. Because of the judged interactions among the events, there was an increase in the final probability of occurrence of identified events. CIT was found to be a suitable methodology for this research and for similar situations in which a proposed single development will predictably involve many interactions, not only with the existing situation but also with secondary events generated by the originally proposed development.

The techniques associated with technological forecasting are more advanced in their range of applicability than in their technology. They currently are being employed in a very broad spectrum of economic, social, environmental, and even political contexts (1). Some of the most common forecasting methods (regression, committee, analogy, delphi, morphological, factor-analysis, discriminant-analysis, system-dynamics, trend-extrapolation) have been developed for purposes of "man-technique dialogue" and are very sensitive to human knowledge and human capacity for imaginative thinking, technical and value judgment, and synthesis.

Some of the above forecasting methods suffer from a variety of problems due to their mathematical nature. For example, some tend to be readily quantified but exclude variables that, although important, are basically subjective in nature. Another shortcoming is that some are highly technical in nature and thus tend to inhibit policymakers from using them freely. Hence a barrier is erected between those who formulate and conceive simulation techniques and those who should ultimately use their output.

It was the purpose of this research to try to use a simulation procedure such as the cross-impact technique (CIT) with which the technically unsophisticated could quickly become experienced. In addition, the scope of this simulation technique is sufficiently wide so that it would express the interaction of competing variables in a realistic and numerical fashion. CIT was used to help forecast the long-range developmental impacts of a proposed railway system that would connect Pakistan, Iran, and Afghanistan (the PIA region).

The proposed link, named the Karachi-Rasht Railway (KRR), extends about 3200 km (2000 miles) from Karachi (on the Persian Gulf) to Rasht (on the Caspian Sea). As shown in Figure 1, the missing link of 1102.2 km (685 miles) extends from Chaman, Pakistan, to Mashad, Iran. The construction of this double-track, broad-gauge link railroad is to begin at Mashad and would require five years at the cost of approximately $244 million. The cost estimate is based on new railway construction unit costs in Pakistan (3).

KRR would benefit the region's overall economy and produce longand short-range developmental impacts. Furthermore, it would connect the Persian Gulf to the Caspian Sea and subsequently, by other modes, the Black and Mediterranean Seas. In addition, it would become an alternative to the Suez Canal by connecting Asia to Europe and Africa by a revival of the old silk-merchants' route used by Marco Polo to reach China. In addition, it would serve as an international link that would connect India, Nepal, and Bangladesh by rail to the USSR and Europe. It would also become a future link of the Trans Asian Railway that connects Asia to Africa and Europe.

The PIA countries are economically dependent on each other and on the advanced nations. There are especially high demands for raw materials; petroleum products; machinery; coal, iron, and steel products; fertilizers and chemicals; grains and grain products; sugar; and livestock.

There are several existing routes (roads and ship and rail) through Turkey, the Cape of Good Hope, the Suez Canal, USSR, and Iskenderun. A comparison of these routes with KRR in terms of transport costs and transit times based on various shipments such as electrical, iron, and steel products revealed that KRR generated the lowest transport cost and time (4).

In realizing the advantages attached to an international integrated transport system (e.g., the African Railway of Uganda, Kenya, and Tanzania; the European railroads of Switzerland, Germany, and France; the Pan American Highway; and the Suez Canal), the proposed railway as an international single entity might become a powerful factor in enhancing the overall development of the region.

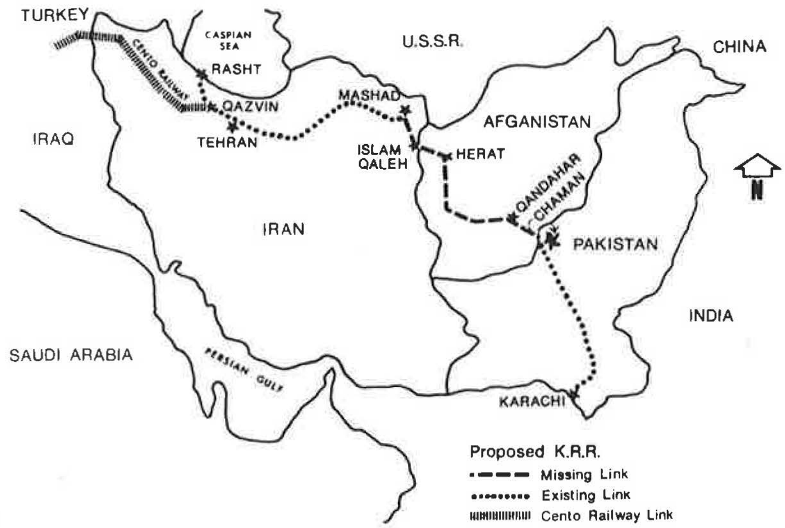
An analysis of analogous transportation links such as the Suez Canal was made to identify events that might be affected by the future impacts of KRR. The socioeconomic characteristics of the PIA region were also investigated to identify the level of developmental events and the magnitude of their resultant changes relevant to the developmental impacts of KRR. In the process of carrying out this project, the PIA region's socioeconomic characteristics were compared with those of two other multi-country regions linked internally by an international railway system.

The region selected in Africa is Uganda, Kenya, and Tanzania (UKT) and that in Europe is Switzerland, West Germany, and France (SGF). The UKT region has socioeconomic characteristics similar to those of the PIA region; Uganda is landlocked, as is Afghanistan. Although Switzerland is likewise landlocked, the SGF region obviously has different socioeconomic characteristics but does represent a level to which the PIA region may eventually rise. The purpose behind such comparisons was to help estimate the future levels of the PIA region's development that might result from the KRR. These studies (the Suez Canal and the UKT, SGF, and PIA regions) and their developmental-impact analysis helped identify events and estimate the future levels of the PIA region's development resulting from KRR.

FORMULATION AND APPLICATION OF CIT

The future impacts of KRR cover institutional elements, demography, social attributes, environmental conditions, values, and economic aspects. They are interrelated in a complex system that most individuals are simply unable to follow. They assume

Figure 1. Proposed Karachi-Rasht Railway (KRR).



independence of its various parts. CIT aims to alleviate this difficulty and probe the effects of interaction among elements of the system even when all the specifics of the situation are not known.

The process of combining a large number of forecasts usually involves comparison of individuals on a pairwise basis to determine whether there are any significant interactions. If so, it may then be necessary to trace through several connections to determine the overall impact. For instance, two events may not interact directly, but one of them may interact with a third, which in turn interacts with the second. Tracing all the links of interactions can be a very tedious and time-consuming process. CIT automatically locates and analyzes these interactions. The general notion of CIT was first suggested by Gordon and Haywood (4). Figure 2 presents the systematic steps required to formulate and use CIT in this research.

A small-scale example of three identified events relevant to the impact of KRR is presented in Table 1. Columns 4-6 of Table 1 show the interaction among the events (which were selected on the basis of my judgment). Basically, each event has been connected with each of the other events; each interaction has three characteristics: mode, strength, and predecessor. The first characteristic, mode, is indicated by a plus or minus sign; the former indicates the enhancing effect, and the latter indicates an inhibiting one.

The second characteristic, indicated by the first digit after the decimal point in columns 4-6 (Table 1), is the strength of interaction, which varies from 0.0 to 0.9. The variation is used to characterize the strength of interaction of occurrence of one event on the probability of a succeeding one (0, weakest effect; 0.9, strongest effect). Clearly, some events will be strongly linked; that is, the occurrence of one produces a large change in the probability of the second. If other events are weakly linked, then the probability of one is only slightly affected by the occurrence of the other. The second digit after the decimal point in columns 4-6 is the predecessor relationship. If it is 0, 1, or 2, the preceding event is immaterial, likely, or necessary, respectively, for the occurrence of the particular succeeding event.

In Table 1, the second column indicates the initial probability of occurrence of each event; this is always assumed to be 0.50. The initial probability is part of the CIT input requirement; it is combined with other variables such as mode, strength, and time to estimate the final probability of each event. The time-lag characteristic refers to the time constant of the change in probability of the affected event in the presence of the occurrence of the prior one. Suppose that two events are strongly linked in the enhancing mode. Even though the linkage is strong, there is little chance that the probability of the second will significantly increase immediately after the occurrence of the prior event. Depending on the nature of the events, the time required to realize the higher probability will range from minutes to decades.

In general, the estimation of the cell entries is a matter of expert judgment. Assuming that we have a large list of n events designated E_1, E_2, ..., E_h; E_i, ..., E_n with associated probabilities $Pr(E_1)$, $Pr(E_2)$, ..., $Pr(E_i)$, ..., $Pr(E_n)$, then the following question can be posed.

If $Pr(E_1) = 1.00$ (i.e., E_1 surely happens), how do $Pr(E_1)$, $Pr(E_2)$, $Pr(E_3)$, ..., $Pr(E_i)$, ..., and $Pr(E_n)$ change (2)?

A simplification is necessary between the initially specified probability $Pr(E_i)$ for each event and its revised probability $\grave{P}r(E_i)$ when the interactions with other events are taken into account. Generally, $\grave{P}r(E_i)$ will depend on $Pr(E_i)$, the mode and strength of interaction with each other event h, and dates on which the event h occurs. Then one might expect the following equation:

$$\grave{P}r(E_i) = f[Pr(E_i), M_{hi}, S_{hi}, t_h, t] \quad (1)$$

where

- $\grave{P}r(E_i)$ = final probability of occurrence of event i, that is, the probability at horizon year t;
- $Pr(E_i)$ = initial probability of occurrence of event i at time t;
- M_{hi} = mode of interaction between events E_h and E_i;
- S_{hi} = measure of strength of connection between h and i, a number between 0.0 and 0.9, the smaller of which represents the weaker strength (0.0 designates an unrelated pair); and
- t_h = original estimate of time for occurrence of development h.

Gordon and Haywood (4) assumed the relationships between $\grave{P}r(E_i)$ and $Pr(E_i)$ to be quadratic:

$$\grave{P}r(E_i) = A[Pr(E_i)]^2 + BPr(E_i) + C \quad (2)$$

Then, by substituting known end conditions, they obtained the following:

$$\grave{Pr}(E_i) = -A[Pr(E_i)]^2 + (1 + A)Pr(E_i) \quad (3)$$

They assumed for both the inhibiting and enhancing modes that when $Pr(E_i) = 0$, $\grave{Pr}(E_i)$ must equal 0, and when $Pr(E_i) = 1$, $\grave{Pr}(E_i)$ must equal 1.

When the influencing event occurs at the horizon year ($t_h = t$), there is no time allowed for the adjustment of the probability of $Pr(E_i)$ to $\grave{Pr}(E_i)$, so $\grave{Pr}(E_i)$ must equal $Pr(E_i)$.

For the enhancing case:

$$0 < A < 1 \quad (4)$$

For the inhibiting case:

$$-1 < A < 0 \quad (5)$$

The question still remained how t_h, t, and S_{hi} affected A. Although greater sophistication was possible, Gordon assumed the relationship to be linear:

$$A_{hi} = M_{hi}S_{hi}[(t - t_h)/t] \quad (6)$$

where M_{hi} is +1 or -1, as determined by the modes, and S_{hi} is a number between 0.0 and 0.9 as previously defined.

Now substituting back into Equation 3, we obtain the following equation:

$$\grave{Pr}(E_i) = -M_{hi}S_{hi}[(t - t_h)/t]\,[Pr(E_i)]^2 + \{1 + M_{hi}S_{hi}[(t - t_b)/t]\}\,Pr(E_i) \quad (7)$$

In words, Equation 7 indicates that the sooner event h starts the horizon year and the greater the strength of connection between events i and h, the greater the change in the revised probability $\grave{Pr}(E_i)$ (1). There still remain some theoretical questions about Equation 7. These are as follows:

1. The quadratic form intuitively appears to have the proper shape, but the accuracy of the relationship of $\grave{Pr}(E_i)$ versus $Pr(E_i)$ and particularly the following boundary conditions are questionable: $\grave{Pr}(E_i) = 0$, when $Pr(E_i) = 0$; and $\grave{Pr}(E_i) = 1$, when $Pr(E_i) = 1$. These conditions do not necessarily hold, since the longer year probabilities are not always 0 or 1 when the initial probabilities are 0 or 1, respectively.
2. The accuracy of judgment on the mode, strength, and predecessor relationship is questionable. No matter how explicit the investigator is about the relationships believed to be functioning in the field, human error still exists. Perhaps some of the interactions are not so strongly linked as they were thought to be.
3. Estimation of the final probability of E_i by time t, prior to the occurrence of E_h, is questionable when $t_i > t_h$.
4. The strength parameters and time lag have not been related by Gordon; in reality, they should be. Such independent treatment of S and the time lag does not permit the quadratic parameter A to assume its full range of values.

Twenty-five developmental events relevant to the impact to KRR were identified and are presented in Table 2. The events were chosen in 1977, before the crises in Afghanistan and in Iran. At that time, the significant consideration was that KRR would enhance regional cooperation. As a result, the PIA region would become politically united and strong enough to reduce any chances of Russian invasion.

The cross-impact relationships of these 25 events and their current and projected levels were analyzed in a fashion similar to that presented in Table 1. The values of M_{hi} and S_{hi} (the mode of interaction and a measure of strength of connection between h and i) were based on my judgment and were developed by comparing each pair of events at a time. Equation 7 was programmed with the mode, strength, and predecessor relationships for the 25x25 event pairs. An event was selected from among the predecessor group and, by using random numbers, a decision was made whether the event occurred. If it

Figure 2. Systematic phases required to formulate and use CIT.

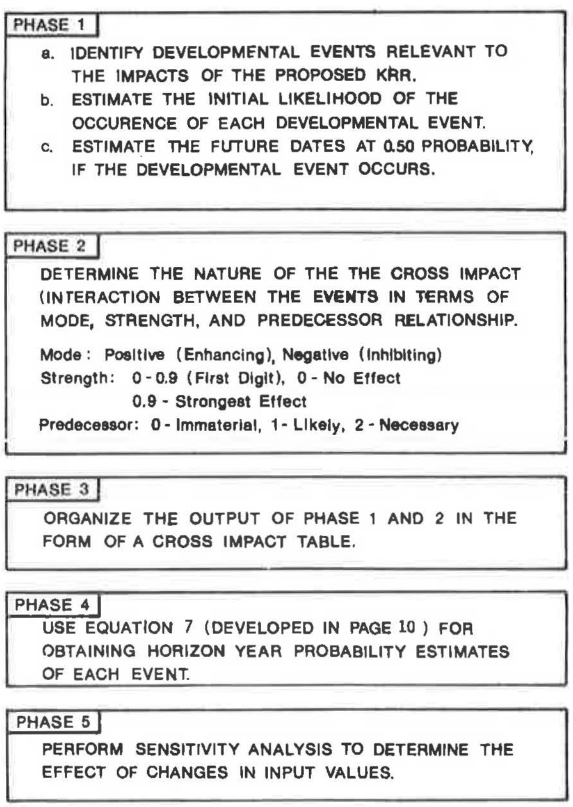


Table 1. Cross-impact for sample of three developmental events related to KRR.

Event	Assumed Initial Probability of Occurrence of Event [$Pr(E_i)$]	Assumed Date of Event (t_i)	Change in Event[a]		
			Increase in Urban Population (E_1)	Increase in Food Production (E_2)	Increase in Life Expectancy (E_3)
Increase in urban population (E_1)	0.50	1984		-0.31	-0.41
Increase in food population (E_2)	0.50	1982	+0.51		+0.82
Increase in life expectancy (E_3)	0.50	1990	+0.51	+0.71	

[a]First digit, strength (0.0-0.9); second digit, predecessor relationship: 0, immaterial; 1, likely; 2, necessary.

Table 2. Events by order of final probability.

Event[a]	Date	Delta	Final Probability	Final Rank
E_6: Energy consumption per capita	1986	0.466	0.966	1
E_9: Urban population	1984	0.388	0.888	2
E_{11}: Life expectancy	1990	0.380	0.880	3
E_8: Daily newspaper circulation	1985	0.363	0.863	4
E_{12}: Population/hospital bed	1995	0.347	0.847	5
E_{13}: Infant mortality rate	1980	0.341	0.841	6
E_4: World Bank lending	1978	0.324	0.824	7
E_{20}: Political harmony	1993	0.305	0.805	8
E_{25}: Removal of visa	1992	0.256	0.756	9
E_{19}: Religion	1985	0.255	0.755	10
E_{23}: Archeological discovery	1987	0.234	0.734	11
E_3: Rail route length	2003	0.210	0.710	12
E_5: Tourist receipts	1985	0.192	0.692	13
E_{15}: Gross national product (GNP)	1989	0.184	0.684	14
E_{10}: Food production	1982	0.179	0.679	15
E_{18}: Exports	1989	0.179	0.679	16
E_{14}: Adult literacy rate	1991	0.177	0.677	17
E_2: Total number of vehicles	1980	0.170	0.670	18
E_1: Road network length	1980	0.158	0.658	19
E_{22}: Removal of tariff and taxes	1985	0.151	0.651	20
E_7: Electric consumption per capita	1985	0.144	0.644	21
E_{21}: Use of railway by nomads	1980	0.135	0.635	22
E_{17}: Imports	1986	0.128	0.628	23
E_{24}: Television in Afghanistan	1982	0.086	0.586	24
E_{16}: Foreign aid	1983	0.018	0.518	25

[a]For each event, an initial probability value of 0.50 was assumed.

did, the probabilities of the remaining events were adjusted and the "play" was repeated for the next event selected. The process was repeated until all events had been decided. This single run-through was repeated 1000 times to produce stable final probability estimates.

ANALYSIS OF RESULTS

The outputs of the first trial are presented in Table 2. Included are events considered, probability initially assigned, delta (the difference between the initial and the final probabilities), the final probabilities (which show the shifts that occurred when the interactions between events were correlated), and the final rank according to initial and final probabilities.

The following conclusions can be drawn from this application for CIT:

1. The judged interactions among the events significantly changed the initial probabilities. For example, E6 (energy consumption per capita in Table 2) was initially thought to have a probability of 0.50 in 1986. Consideration of the interactions raised this to 0.966 for the horizon year, 2003. The 0.966 probability of increased energy consumption per capita from the existing level of 199 equivalent kg of coal (439 lb) to the projected level of 299 equivalent kg of coal (659 lb) suggested that, by 2003, under the impact of KRR, travel, exports, imports, and agricultural and industrial activities would significantly increase. This provides a clear warning to the PIA region's policymakers concerning energy-conservation measures to cope with their current and future domestic needs, especially in the context of the current export of energy.

2. The estimated final probability of occurrence of the PIA region's increase in life expectancy is 0.880, an increase of 0.380 over the probability initially assessed. In addition, the region's population per hospital bed and infant mortality rate were predicted to decrease. The estimated final probabilities of occurrence of these events are 0.847 and 0.841. Furthermore, the final probability of increased World Bank lending is estimated at 0.824. Increased loans would add a new capital that would cause the PIA region's governmental share of health expenses to rise and might affect life expectancy and increase health levels.

3. The final probability of occurrence of the PIA region's increased per-capita GNP and literacy rate has shifted from 0.50 to 0.684 and 0.677, respectively, which suggests that the increased mobility provided by KRR would help increase the region's schools and school enrollment. It is assumed that an increase in the literacy rate will increase per-capita income.

4. With reference to the increase in political harmony in the PIA region and to removal of visa requirements, tariffs, and taxes, there was also a significant probability gain (Table 2), which suggests that KRR would increase trade and regional cooperation, thus enhancing peace and prosperity in the region and increasing tourism and cultural and religious activities.

The above lists of conclusions should serve to illustrate the kinds of inferences that can be drawn from a cross-impact analysis.

SENSITIVITY ANALYSIS

After completion of the initial computer runs, the final step is to test the sensitivity of the probability shifts in response to alterations in the original probability levels. Each event was increased 30 percent from its assumed initial probability (0.50 to 0.80). In addition, the date of each event was altered to reduce by half the time period from the assumed inception of KRR (1978) to the occurrence of the event. For instance, an event that was originally predicted for 1980 was now predicted for 1979, one for 1974 now for 1981, and so forth.

The magnitude of these changes can be measured by the sensitivity factor (SF). The mathematical relationships are established as follows:

$$SF(E_i) = [\ddot{Pr}(E_i) - Pr(E_i)]/\Delta Pr(E_i) \quad (8)$$

$$\Delta Pr(E_i) = \overline{Pr}(E_i) - Pr(E_i) \quad (9)$$

where

$SF(E_i)$ = sensitivity factor of event i,
$\ddot{Pr}(E_i)$ = final probability of event i obtained after its initial probability was changed from 0.50 to 0.80,
$\grave{Pr}(E_i)$ = final probability of event i obtained by assuming the initial probability of 0.50,
$\overline{Pr}(E_i)$ = initial probability of event i after it was raised from 0.50 to 0.80 for sensitivity-analysis run, and
$Pr(E_i)$ = initial probability of event i before sensitivity-analysis run (initial probability = 0.50).

Equation 8 was then incorporated into the previously described CIT computer program and a run that had 1000 iterations was made for each alteration. Several illustrations of interesting results from the sensitivity analysis are presented below.

1. Figure 3 presents one example of the sensitivity-test results and shows the direct and indirect impacts of E_{15} (increased GNP). E_{15} directly affects or is affected by the following:

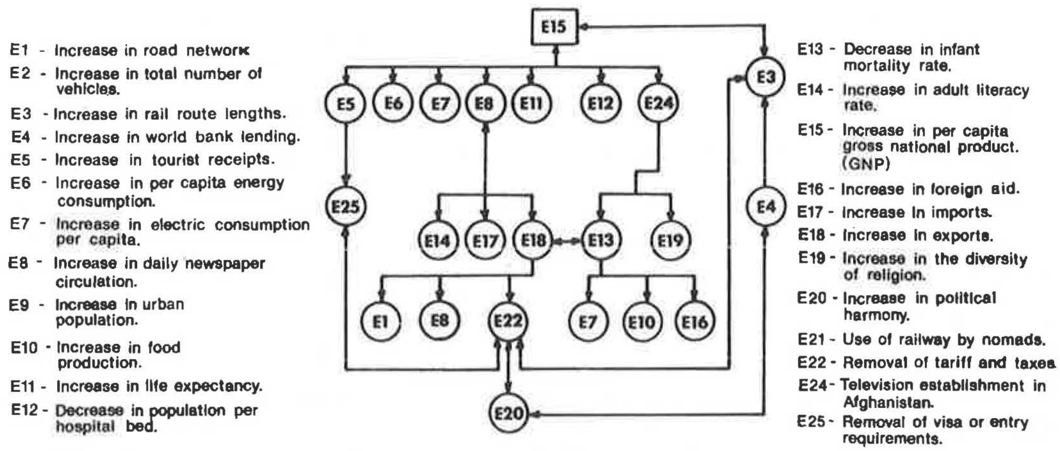


Figure 3. Significant direct and indirect relations between per-capita GNP and other events.

E_5: Increase in tourist receipts,
E_6: Increase in per-capita energy consumption,
E_8: Increase in daily newspaper circulation,
E_{11}: Increase in life expectancy,
E_{12}: Decrease in population per hospital bed, and
E_{24}: Establishment of television in Afghanistan.

For instance, tourist spending is an attractive source of foreign-exchange earnings. It can be seen in Figure 3 that increases in such spending have a significant positive effect on the per-capita income and indirectly enhance the removal of visa requirements from the region.

2. Food production is an important development that is significantly affected by the increase of rail route length and foreign aid. It was found that food production has a direct effect on decreasing the infant mortality rate and its substantial relations with other events. Foreign aid seems to affect electric consumption per capita and the establishment of television in Afghanistan. This seems to be rather realistic and applies mostly to Afghanistan and Pakistan since a large share of their capital expenditure comes from foreign aid. The most direct and significant effect on foreign aid is food production. To attract foreign aid, it seems that the PIA region must initiate proper agricultural planning policies to increase food production.

3. Life expectancy was significantly affected by the number of hospital beds. Increased literacy rate and per-capita income also increase life expectancy. An increase in per-capita GNP may affect life expectancy, too, but only through the ability of KRR countries to provide better food and to develop medical and sanitation facilities.

4. An increase in the literacy rate directly affected per-capita energy consumption, daily newspaper circulation, life expectancy, and the number of hospital beds. The literacy rate directly influenced the per-capita income and indirectly influences and is affected by the increase in per-capita electric consumption, imports, and exports.

5. It is found that political harmony in the PIA region has a positive impact on increased World Bank lending and also enhances the removal of tariff and taxes from the region. Furthermore, it indirectly affects and is affected by the increase in exports and removal of visa formalities. It must be emphasized that, due to political uncertainty, KRR countries' large and unforeseen commitments for defense expenditures have diverted funds from many developmental projects.

Many of the existing problems in the region can be solved best through a cooperative approach among KRR countries. In a region in which resources are unevenly distributed and the size of most national markets is restricted by inaccessibility and political problems, regional cooperation is mandatory. Furthermore, the establishment of ties within the KRR region could reduce chances of Russian invasion.

CONCLUSIONS AND RECOMMENDATIONS

It must be pointed out that this research was completed in 1977 and the following conclusions and recommendations were derived at that time:

1. The proposed KRR would significantly reduce the current high transportation costs, delay, and congestion in the PIA region. Furthermore, it would become an important means of bringing peoples of the region together and would lower the barriers that now interfere with concerted efforts toward development.

2. The proposed KRR should be constructed and used as an integrated single system (under an independent organization composed of commissioners elected from the PIA region). If the link were used as an integrated international system (as has proved to be useful in the case of the international railways of the UKT and SGF regions), it would compete with the Suez Canal and other major existing routes in connecting Asia to Europe and Africa. The locational analysis for the proposed KRR involves a complete field-engineering investigation that gives full consideration to environmental impact and land use.

3. CIT should be validated and particular attention should be given to the structure of Equation 7, the uncertain accuracy of $\check{P}r(E_i)$ versus $Pr(E_i)$, and the accuracy of judgments on mode, strength, and predecessor relationships.

4. The judged interaction among the events played a vital role in changing the horizon year for the probability of occurrence of each event. In particular, the increased per-capita energy consumption, urban population, life expectancy, newspaper circulation, World Bank lending, political harmony, and food production were among events significantly affected by the interaction relevant to the impact of KRR. The results generated by changes in inputs (sensitivity analysis) made it possible to identify those major contingencies with which to cope and to compare the effectiveness of alternative policies and action programs. For instance, an increase in probability of occurrence of energy consumption provides a clear warning concerning energy-conservation measures. Oil and natural gas are the main sources of energy and the most valuable export items

of Iran and Afghanistan. At this time Afghanistan does not make full use of its natural gas and its potential for the generation of electricity. The former (which accounts for 11 percent of the country's exports) is all exported to the USSR; in the PIA region, wood is a scarce resource used for heating homes and industries and for cooking. Natural gas or electricity could be substituted for this purpose.

The results of CIT can also be used during the planning phase. For instance, a scenario in which drought was imposed as an uncontrolled event was added to Table 2 with a 0.50 probability of occurrence by the year 1990. After its relations with the other events had been determined, the resulting 26x26 matrix was used as a basis for a single run through 1000 interactions. The drought decreased the final probability of occurrence of the following events by 0.30-0.40:

E_{11}: Increase in life expectancy,
E_{13}: Decrease in infant mortality rate, and
E_{10}: Increase in food production.

The conclusion from this analysis is that agricultural productivity and food-storage capacity must be increased to cope with food shortages. Similar to drought, other unexpected events (war, invasion, etc.) should also be added to test their impacts during the planning phase.

In general, the proposed KRR, its impact-identification process, and the application of CIT to measure the overall developmental effects of the railway were analyzed in a systematic fashion that might serve as a model for similar undertakings.

Other potential events should also be tested to measure their likelihood of occurrence relevant to the construction of KRR. To enhance sound economic development and to maximize the efficiency of investment, all the region's modes of transportation should be used.

ACKNOWLEDGMENT

My greatest debt is to J.W. Dickey, to whom I owe my entire academic career. His long hours of consultation and guidance enabled me to complete this project as part of my Ph.D. dissertation, done at Virginia Polytechnic Institute and State University, Blacksburg, Virginia, in 1976-1977. I also wish to thank Susan Marchesano for typing this paper.

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Forecasting Economic and Demographic Change in Slow-Growth Economy

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Application of a regional population and employment forecasting model to a slowly growing metropolitan area, the Kansas City Metropolitan Region, is discussed. The model used integrates an econometric approach to employment forecasting with a cohort-survival approach to population forecasting. The labor-market adjustments required to ensure that the demand for and supply of labor are in equilibrium are based on the proposition that labor supply continually responds to labor demand. The major problem encountered in applying the model to the Kansas City Metropolitan Region was employment forecasts that did not correspond to current trends or theoretical expectations and that arose because of inconsistent modeling of the labor supply-and-demand interactions. Once the model had been respecified, reasonable forecasts were achieved. The implication for other slowly growing areas is that some current methods of modeling metropolitan growth may not adequately capture the nature of a stagnant economy. The magnitude of factors that are relatively uncertain, such as unemployment and labor-force participation rates, becomes critically important in such economies because there are few other sources of change in the supply of labor. The adjustment of such factors must therefore be made explicit in the forecasting process. This is the first part of an overall forecasting effort currently being implemented under several federally sponsored programs by the region's metropolitan planning organization, the Mid-America Regional Council.

One major requirement for planning highway and transit improvements, future economic development needs, and infrastructure additions and for analyzing impacts of air and water quality is information about future population and employment growth and location. These types of analyses are the charge of the metropolitan planning organization of the Kansas City Metropolitan Region (KCMR), the Mid-America Regional Council (MARC). However, in the past MARC has not always been able to construct these analyses by using soundly developed economic and demographic information. The data often did not reflect the most current information and were available for a very limited set of variables. Also, there existed no method by which the effect of currently interesting policies could be systematically examined for their impact on people and jobs. To aid in the provision of better information so that decisions based on MARC's analyses take into account a more realistic idea of future development consequences, MARC decided to implement a set of state-of-the-art computerized forecasting models.

The regional forecasting process engaged by MARC can be divided into four major steps; each step examines the metropolitan region from a slightly different perspective. The first step examines the region's overall potential for economic and population growth. The second step examines the effect of regional growth on small areas within the region.

The third step analyzes the travel demands that result from the forecast activity distribution. Finally, the outputs from the first three steps are combined to assess the impacts of various policy alternatives. The purpose of this paper is to describe the development and results of the first step in the overall forecasting process, the forecasting of population and employment for KCMR as a whole.

OVERVIEW OF KCMR ECONOMY

According to the Bureau of Economic Analysis, KCMR has experienced continued growth in employment since the 1950s (1). The current growth rate in employment is approximately 2 percent/year, which is about the same as it has been in the past. However, the rate of employment growth in KCMR has fallen relative to that for the nation since 1950 and is in fact currently below that for the nation for the first time in more than 30 years.

Census Bureau figures for 1950, 1960, and 1970 indicate that the population growth in KCMR has decreased dramatically from 1950 to 1978 (2), and there has been a far more severe decline in KCMR than in the nation as a whole. Indeed, the region's population growth rate is now about half that of the nation (3). Part of the explanation for this lower growth in population is that the labor-force participation rate (LFPR) is higher than average in KCMR, especially the participation rate of women. To meet a growth in employment similar to that of the nation, KCMR has historically required less population to supply the appropriate quantity of labor. Moreover, the region's labor force is highly mobile in response to changes in employment prospects. Census Bureau figures indicate a net out-migration of approximately 30 000 from 1970 to 1978.

Although such mobility has kept the KCMR unemployment rate down (it averages about 1.25 percentage points less than that for the nation during the 1970s, according to figures from the Kansas and Missouri Divisions of Employment Security and Census Bureau statistics for 1979), this also points to a problem. The KCMR economy has not created sufficient jobs to retain all its potential labor force in the region and resources are being lost to other metropolitan areas.

An examination of the industrial structure of employment reveals the nature of the problem. The industries that grew least relative to growth for the nation during the 1970s are mining, manufacturing, transportation, communications and public utilities, and wholesale trade. With the exception of mining (which is of little significance in KCMR), these are industries in which KCMR has traditionally enjoyed a competitive advantage due to its location in the geographic center of the country and at the intersection of two major rivers. Yet they are precisely the industries that are not competing well with those of other regions, and this is reflected in the demand for labor. The other sectors of the economy grew at rates comparable with or exceeding those of the nation. However, they are not industries that take particular advantage of KCMR's locational characteristics. Without strong growth in the industries that can take advantage of its central geographic location, KCMR's ability to attract factors of production from other areas or even maintain its existing factors will continue to represent a major problem.

REGIONAL FORECASTING METHODOLOGY

Major Assumptions

For the regional forecasts, two major assumptions were made concerning the interaction between the economy and the population:

1. Labor supply adjusts to labor demand, and
2. Several different mechanisms exist by which labor supply can adjust to labor demand.

Labor Supply and Labor Demand

Although on a national level labor supply and demand are interdependent, at the metropolitan level it is more appropriate to forecast the labor force as being determined by labor demand. Consider the case in which there is a labor shortfall. At the national level, excess demand for labor results in higher wages and a shift toward capital investment to make existing labor more productive; both of these results contribute to a lessened labor requirement. At the metropolitan level, however, such a restraining mechanism is greatly weakened. A metropolitan area in which job opportunities exceed available labor can draw migrants from areas in which the reverse situation is true. The same dichotomy holds in the case of a labor surplus. At the national level, a surplus of labor tends to lead to the substitution of labor for capital as the price of labor falls. But at the regional level, rather than accept a lower wage or unemployment, a more likely response would be for labor to relocate where there is availability of employment.

The regional forecasting model in this study uses national projections of employment to capture the effects of national trends in labor demand and supply. However, once these effects have been taken into account, the assumption is made that demand-supply forecasts are reconciled through supply-side adjustments.

Adjustment Procedures

Changes in the level of net migration, participation rates, and unemployment are perhaps the most readily perceived long-term consequences of an imbalance in a metropolitan region's labor market. Other possible adjustments that can bring labor supply into balance with labor demand include (a) change in wage rates, (b) more efficient use of relatively scarce resources, (c) development of new technology, (d) shift in the type of occupations held from those no longer required to those in demand, (e) change in the rate of commuting into the region, and (f) change in the number of people who hold more than one job.

There is a great deal of uncertainty and little empirical evidence about the relative magnitude of such responses to a given imbalance in the labor market. No model has been developed to satisfactorily predict these types of changes. Yet the relative magnitude of the changes is important because it determines the level of population required for a given employment level.

Model Selection and Original Specification

For the purpose of regional forecasting, the Interactive Population and Employment Forecasting (IPEF) model was selected (4). This model was developed in San Diego and used successfully there and in Dallas-Fort Worth; both of these are rapidly growing regions. Designed to produce medium- to long-range demographic and employment forecasts, the original IPEF model integrates two fundamental forecasting techniques: a cohort-survival method of population forecasting and an econometric approach to employment forecasting. As a result, IPEF is sensitive to the interdependence of demographic and economic forces within a particular region.

In the demographic sector, births are calculated from projections of national age-specific fertility rates (5). Deaths are calculated from national projections of survival rates by age and sex. Aging the previous period's population by five years, adding the births, and subtracting the deaths yields the change in the natural population by age and sex. The final component of population change--net migration--is determined endogenously by the model through the interaction between labor supply and demand.

The region's available labor supply is calculated by multiplying age-specific LFPRs by the natural population by age and sex and summing over all age and sex groups. Through the application of an assumed unemployment rate, a net commuting rate, and a ratio of jobs per employee, this figure is converted to the maximum available supply of labor, which is then compared with the labor demand yielded by the independent employment forecast.

The econometric models used to forecast employment are calibrated on historical data (6,7) to find the past relationship between the dependent and independent variables. The relationship is then applied to exogenous projections of the independent variable to calculate projections of the dependent variable. In the IPEF model, the dependent variable is place-of-work employment for each industrial sector. The independent variable varies as a function of the basic or service characteristics of the industry.

Basic industries are exporting industries, and since they serve national markets, employment in a basic industry at the regional level is assumed to serve exactly the same market as employment in the same industry nationally. National projections of employment are available from the Monthly Labor Review of the Bureau of Labor Statistics. Therefore, each local basic industry is forecast as a function of the performance of the same industry at the national level.

Local-serving industries satisfy local demand for products. Since local demand for goods and services can only be expressed through the expenditure of local income, service industries are forecast as a function of income. However, since income forecasts are not available, a surrogate variable is used--in this case, population.

Once the industrial employment forecasts have been developed, they are summed to produce a total employment figure. This defines the demand for labor. To ensure a balance between the size of the population and labor-force requirements, the labor supply and demand are compared, and the labor supply is adjusted to accommodate labor demand by changing the amount of net migration. Labor-force migrants are then converted to total migrants based on a ratio of total migrants to labor-force migrants derived from national data (8), and they are added to or subtracted from the natural population.

Such changes in the population result in a revised demand for the goods and services of the local-serving sectors, the employment forecast for which must also be adjusted. This changes the total employment and the required level of net migration. Population changes once more, and the process is iterated until an equilibrium is reached. Upon equilibrium, the whole process is repeated for the next five-year forecasting period.

Respecification of Model for Slow-Growth Economy

The original specification of the model produced forecasts that did not correspond to current trends or theoretical expectations, primarily because it did not adequately take note of the characteristics that make a stagnant economy different from one that is rapidly growing. In KCMR, the industries that are growing fastest are the local-serving industries. They also contribute the largest proportion of the total employment. Because rapid economic growth is usually generated from satisfying a national demand, in rapidly growing areas it is usually basic-industry growth that fuels the economy and to which most of the employment is devoted. Since, in the original model specification, the result of labor supply-and-demand interactions is the determination of the local demand variable, population, the significance of the interactions varies directly with the dependence of an economy on local demand for its employment. Consequently, inconsistencies in the modeling of labor supply-and-demand interactions may not be noticed in rapidly growing areas, whereas in an area in which economic growth is slow, such inconsistencies produce serious problems.

Two examples illustrate the sensitivity of the original model specification to labor-market interactions when applied to a slowly growing economy. First, the iterative process described in the preceding section takes longer to equilibrate labor supply and demand when a relatively large segment of the economy depends on the final level of labor supply than when the major portion depends on exogenously generated demand. Over the period 1970-1975, when, in fact, substantial out-migration occurred, the model continued to iterate in response to the perceived excess supply of labor until it predicted an employment decline from 600 000 to 100 000. Actual employment rose slightly over the period.

Second, the model produced unrealistic employment forecasts in response to assumed changes in such labor-supply variables as LFPR, unemployment, net commuting, and jobs per employee. A reduction in the forecast LFPRs by 1 percent (which allows more people to reside in an area, given an employment level) resulted in a 15 percent increase in the local-serving employment growth forecast for the projected period. However, since the people added are not in the labor force, it is difficult to understand why their inclusion should result in an increased locally generated demand for goods and services.

As may now be obvious, the reason the original model specification did not adequately capture the nature of a stagnant economy is that it did not completely abide by the first major assumption outlined earlier--that labor demand be forecast independently of labor supply. Because local-serving employment, a labor demand variable, was being forecast as a function of population, a labor supply variable, the two were made interdependent, which (as was explained in the earlier section) is an unrealistic model of metropolitan labor-market interactions. Therefore, it was decided to use another variable to forecast local-serving employment. However, as the importance of the labor supply variables to a slowly growing economy became obvious, it was also decided to examine the impact of their adjustment process on final population levels more explicitly. The assessment procedure is described in the next section.

One of the difficulties associated with econometric models is their requirement for estimates of the independent variables to make forecasts of the dependent variable. The independent variable must be forecast either exogenously or by the model itself. Exogenous projections of a local demand variable are, however, extremely difficult to make. The IPEF model also does not produce forecasts of such variables endogenously. Therefore, it was decided to adopt employment in the same industry at the national level as the independent variable in forecasting local-serving employment. This makes the functional form of the local-serving model identical to that of the basic industries, which thereby eliminates any explicit reference to base theory. Implicitly, however, base theory still operates. The new functional specification implies that KCMR's local-serving industries are functions of certain national trends--productivity increases, increased white-collar employment, larger union contract settlements--that affect the amount of local income spent on service-oriented products. No local variable remains, however, to separate KCMR industries from their national counterparts.

The revised IPEF model used in KCMR is therefore somewhat less complicated than the original model. However, it is also more theoretically robust, which allows the effects of factors that would normally be concealed in a high-growth economy to be captured more accurately. The specification of the revised model is shown in Figure 1.

Labor-Market Adjustment Procedures

The initial estimates of labor demand and labor supply are independent of one another, and although historically they represent independent estimates of the same identity, in making forecasts there is an expectation that they will not balance. The reconciliation of the initial supply-demand forecasts is achieved through the labor-market adjustment process, to which we now turn.

As explained earlier, there are several mechanisms by which labor supply can adjust to labor demand. They include changes in net migration, rate of unemployment, LFPRs, net commuting, occupational shifts, technology, productivity, average number of jobs held per employee, and wages. For the purpose of this study, only changes in net migration, rate of unemployment, and LFPRs have been considered. Together they represent the most significant supply-side adjustments to the forecast supply-demand imbalances. In the case of KCMR, the other factors are considered to be relatively unimportant (net commuting rate and ratio of jobs per employee), too difficult to forecast (changes in technology and wage rates), or deficient in data (productivity and occupational shifts). Except for productivity changes embodied in the national employment forecasts, these are all held constant over the projection period.

The limits to changes in LFPR and unemployment rate were defined based on their maximum historical variation relative to the values recorded for the nation as a whole. Net migration was then assumed to compensate for any remaining difference between labor supply and demand. The extent to which LFPRs and unemployment rates will adjust within these historical limits, however, is uncertain. For each projected labor-market situation there exists a range of possible responses in both of these labor-supply factors. In the absence of any data, an ad

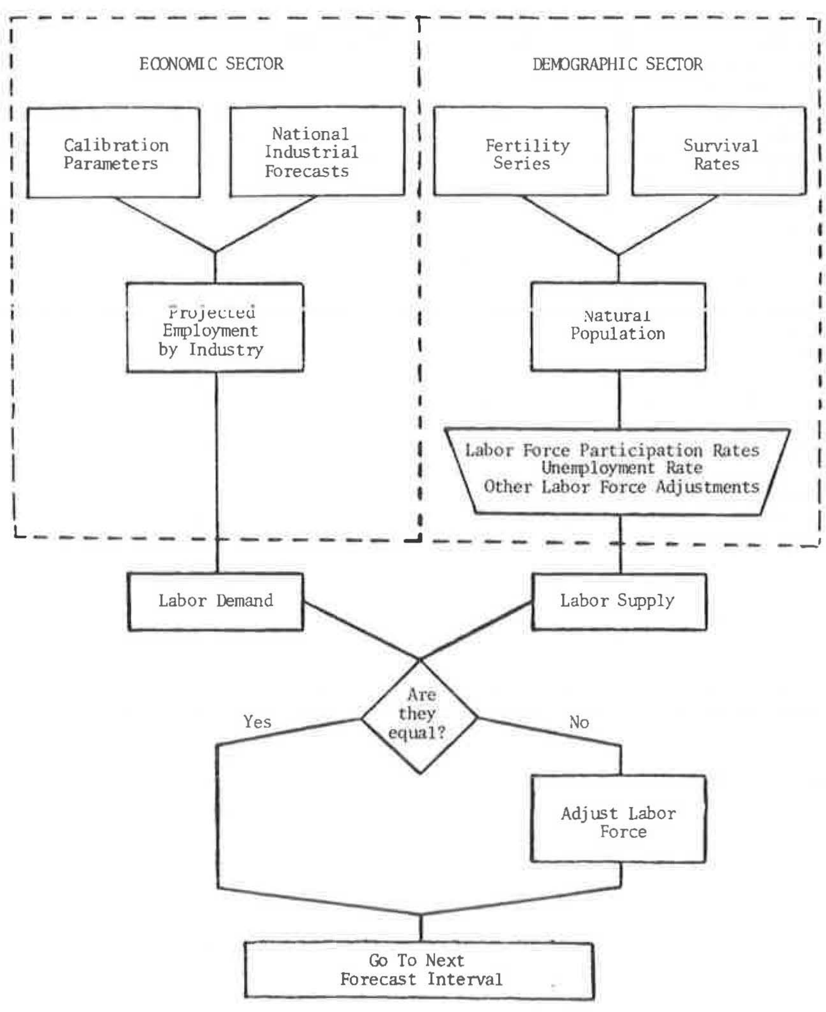

Figure 1. Regional economic and demographic forecasting procedure.

hoc procedure was developed to estimate the probable range of adjustment.

First, the labor-supply adjustments are classified as compatible or incompatible with the direction of the labor-market imbalance. This determines in which direction LFPRs and unemployment rates have the most scope for adjustment. For example, in the case of a labor surplus, compatible adjustments in the labor-supply factors are an increase in the unemployment rate and a decrease in LFPR. Changes in the opposite directions are classified as incompatible and are assumed to be smaller in absolute value than are compatible changes, all else being equal.

Second, the magnitude of the imbalance is classified as small, moderate, moderately large, or large. Given that LFPRs and the unemployment rates can adjust more in one direction (are compatible) than in another (are incompatible), the relative size of the imbalance affects how far in each direction the labor-supply factors can adjust. That is, a large imbalance creates the most pressure for adjustments in the compatible direction, whereas a small imbalance creates the least. Conversely, a small imbalance provides the greatest opportunity for adjustment in the incompatible direction, whereas large imbalances provide the smallest. Based on this discussion, the probable range of supply-side adjustments that occurs for different supply-demand imbalances was estimated. These values are shown in Table 1.

Because the labor-supply factors have a range of possible values for each labor-market situation, the population required to provide the labor force will also have a range of possible values. For example, a labor surplus met by an increase in the unemployment rate or a decrease in LFPR would result in a larger population than if the surplus were to be met by net out-migration. Similarly, a labor deficit met through lower unemployment or higher LFPR would result in a lower population than one met through net in-migration. Table 2 summarizes the interaction between these labor-supply adjustments and the population. The result is that there exists a range of population forecasts for any given employment forecast due to the uncertainty in the response of labor supply to changing labor demand.

The methodology adopted in applying these labor-supply adjustments to create a range of populations at each forecast employment level is as follows. The unemployment rate and LFPRs are first set to their long-run historical average and the model is run for one forecasting interval. The direction and magnitude of the labor-market imbalances can then be observed and classified as shown in Table 1. To generate the high end of the population range for a given employment forecast, the unemployment rate is set at its maximum allowable value, and LFPRs are set at their minimum allowable values. To generate the low end of the population range for the same employment forecast, the unemployment rate is set at the lowest value allowed and LFPRs are set at their highest allowable values.

The new unemployment rate and LFPRs are then input and the model is rerun under each case (i.e., upper and lower population), this time for one additional forecasting period. The projected labor-market situation in this new forecasting interval is then examined and the market adjustments are again introduced so as to produce an upper and lower population range for the given employment forecast. This process is repeated for each forecasting period. Once historical limits are reached, however, the economy is assumed to possess no further scope for adjustment and the labor supply variables are fixed at their historical maximum and minimum values.

Results

Table 3 presents the equations and relevant statistics achieved from the calibration of the respecified IPEF model. The model was calibrated on a 1962-1977 time series of employment by industry from the Bureau of Labor Statistics. All regressions are significant at the 0.95 level. Although more-complicated equations were tested, the simple linear form provided the best-fitting relationships.

The total-employment forecasts for 1970, 1975, 1980, 1985, 1990, 1995, and 2000 are, respectively, 613 004, 659 644, 748 610, 821 290, 872 405, 910 014, and 938 241. The resulting probable population forecasts are presented in Table 4. Also presented are changes in the labor-supply factors required to create the range of populations forecast.

CONCLUSIONS

Implications for KCMR Economy

The essential conclusions to emerge from the study

Table 1. Adjustment probabilities in labor-supply variables for different labor-market imbalances.

			Supply-Side Adjustment (%)			
			Magnitude of Imbalance			
Direction	Classification	Labor-Force Supply Factor	Small (<5000)	Moderate (5000-15 000)	Moderately Large (15 000-20 000)	Large (>20 000)
Surplus	Compatible	LFPR	-1.5	-2.0	-3.0	-4.0
		Unemployment rate	+1.0	+1.5	+2.0	+2.5
	Incompatible	LFPR	+1.0	+0.5	+0.5	+0.0
		Unemployment rate	-0.5	-0.5	-0.0	-0.0
Deficit	Compatible	LFPR	+1.5	+2.0	+3.0	+4.0
		Unemployment rate	-1.0	-1.5	-2.0	-2.5
	Incompatible	LFPR	-1.0	-0.5	-0.5	-0.0
		Unemployment rate	+0.5	+0.5	+0.0	+0.0

Table 2. Interaction between labor-supply adjustments and population.

Direction	Classification	Labor-Supply Adjustment	Population
Surplus	Compatible	Unemployment increase; LFPR decrease	High
Surplus	Incompatible	Unemployment decrease; LFPR increase	Low
Deficit	Compatible	Unemployment decrease; LFPR increase	Low
Deficit	Incompatible	Unemployment increase; LFPR decrease	High

Table 3. Calibration equations and relevant statistics.

Equation	Statistic F-Value	Adjusted R^2	Durbin-Watson
Agriculture = -1454 + 2.41 * U.S. agriculture	329.5	0.96	0.98
Mining = 1109 - 0.66 * U.S. mining	5.1	0.21	2.50
Construction = 14 912 + 2.92 * U.S. construction	11.9	0.42	1.47
Declining manufacturing = 3254 + 751.55 * LDECLMANU	127.0	0.93	N/A
Stable manufacturing = -17 154 + 8.00 * U.S. stable manufacturing	42.9	0.74	1.13
Transportation = -2998 + 15.05 * U.S. transportation	94.7	0.86	2.09
Communications and public utilities = 2289 + 6.15 * U.S. communications and public utilities	106.01	0.88	0.73
Wholesale trade = 7525 + 8.85 * U.S. wholesale trade	1153.3	0.99	1.19
Retail trade = 12 737 + 6.65 * U.S. retail	1978.3	0.99	1.23
Finance, insurance, and real estate = 7824 + 7.02 * U.S. finance, insurance, and real estate	698.2	0.98	0.63
Services = 11 921 + 8.377 * U.S. services	1035.5	0.99	0.59
State and local government = -3784 + 5.63 * U.S. state and local government	2797.6	0.99	1.31
Federal government = -15 264 + 15.36 * U.S. federal government	125.5	0.89	1.45
Military = 15 100 in 1975	N/A	N/A	N/A
= 9410 for every period thereafter			

Notes: LDECLMANU = lagged KCMR declining manufacturing employment.
N/A = not applicable.
Coefficients for U.S. industries are in thousands.

Table 4. Probable range of population and labor-force responses to forecast level of employment.

Year	Population	Labor Force	Net Migration	KLFPR[a]	Unemployment Rate
High Forecast					
1970	1 327 266	594 275	-	-	-
1975	1 398 012	650 793	23 975	0.980	0.054
1980	1 462 517	738 566	21 232	0.970	0.054
1985	1 544 757	803 477	20 921	0.965	0.046
1990	1 632 864	851 697	28 100	0.960	0.044
1995	1 717 033	888 413	30 232	0.960	0.044
2000	1 768 577	915 971	5 471	0.960	0.044
Low Forecast					
1970	1 327 266	594 275	-	-	-
1975	1 351 032	641 303	-23 005	1.005	0.040
1980	1 366 032	720 292	-23 495	1.020	0.030
1985	1 430 476	790 224	12 695	1.030	0.030
1990	1 507 219	839 405	25 146	1.030	0.030
1995	1 587 063	875 591	32 832	1.030	0.030
2000	1 636 634	902 751	9 306	1.030	0.030

[a]KLFPR = multiplier to increase or reduce all KCMR LFPRs by a fixed percentage.

are as follows. First, the pattern of employment growth that has been prevalent in KCMR through the 1970s is expected to continue to be the dominant factor through the forecasting period. This indicates that industries that use the locational advantages of KCMR (manufacturing, transportation, and wholesale trade) will continue to grow much more slowly than industries that serve primarily local demand. This understandably mirrors the prospects for the nation, since the national projections are the input data used to provide KCMR employment forecasts. Yet it also indicates that no major industry makes effective use of the characteristics for which KCMR has a comparative advantage. Otherwise, the region would be better able to dissociate itself from the overall national trends.

Second, unlike the pattern in the 1970s, the relatively slow employment growth in the sectors that require a KCMR-type location will not lead to a loss of population. Even the low-population forecasts indicate a net in-migration requirement to match the demand for labor by the year 1985. Once the post-World War II population growth has been absorbed into the labor force, the natural growth in labor supply is likely to slow down considerably. But since this slowdown in labor supply is a national phenomenon, it raises the question of where the necessary migrant labor is likely to come from. Finally, labor-supply adjustments prove very important to an area that is experiencing slow economic growth, since they determine the level of population consistent with the forecast employment. In KCMR, future population growth could vary by as much as plus or minus 18 percent, depending on the precise response of the labor force to employment opportunities.

Evaluation of Results

The forecasts presented in this paper are probably representative of the upper end of possible economic/demographic outcomes for KCMR. This conclusion results from the combination of three factors. First, the net in-migration required to balance the labor supply and demand may not be achievable. Because the growth in regional employment arises primarily from the sectors that serve local demand rather than those that use KCMR's locational characteristics, the economy's abilities to attract certain types of labor are not being fully exploited. In the face of expected slow growth in the nation's labor supply, it is unclear why KCMR should be able to compete for scarce labor more effectively than other areas.

Second, the national employment forecasts on which the regional forecasts are based are likely to be high. Currently we see signs that a massive infusion of capital will be necessary to reduce the requirement for two components of the production process that are experiencing rapid cost increases--labor and energy. If this trend continues, the labor requirement to achieve the level of output embodied in the current national economic forecasts will be considerably less.

Finally, it is possible that the estimated relationship between KCMR and U.S. industries is too high. It was noted earlier that the KCMR total-employment growth rate dropped below that of the nation for the first time during the 1970s, which indicates a decreasing relationship over time. Since the linear calibration equations include information from periods that experienced faster growth than current periods, the relationship may be overestimated.

In conclusion, the model used to make projections of population and employment for KCMR as a whole required much modification before it could be applied to a slowly growing economy. This was primarily due to inconsistent modeling of the labor supply-and-demand interactions. The result of the respecification was to produce a less complicated but theoretically more robust model that explicitly recognized the importance of labor-supply adjustments. Yet because certain current and future trends are not adequately reflected in the forecasting process, the forecasts must be interpreted as representing the upper end of possible economic and demographic expectations for KCMR. (Further information concerning the forecasts can be obtained from the Mid-America Regional Council.)

ACKNOWLEDGMENT

The research in this paper was funded in part through planning assistance grants from the Urban Mass Transportation Administration and the Federal Highway Administration acting through the Missouri Highway and Transportation Department and the Kansas Department of Transportation. The conclusions are ours and are not officially endorsed by the Mid-America Regional Council.

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Evaluation of Two Residential Models for Land Use Allocation

C. J. KHISTY

The current thrust in transportation planning is to make greater use of manual and partly computerized techniques for providing quick-response travel estimation. In this context, land use models, which fuel the typical transportation models, are needed for small and medium-sized cities that operate on a small budget. The results of the evaluation of two operational residential land-use-allocation techniques most suitable for use in small and medium-sized cities are recorded. In an ex post facto test, both techniques were applied in a common setting and the U-statistic was used as a measure of performance. The results were excellent.

The transportation-planning process formalized in the early 1960s became increasingly diversified in the 1970s. This change also affected models for land use allocation, which fuel the typical four-step sequential transportation models. Recently, special attention has been focused on the planning processes for small and medium-sized communities. This paper records the results of an evaluation of two operational techniques for forecasting residential land use most suitable for use in small and medium-sized cities. The first technique tested is the Chicago Area Transportation Study (CATS) method or the Density-Saturation Gradient (DSG) method, which is a simplification of the CATS method (1). The second technique tested is a method of land use forecasting in which the concepts of holding capacity, logistic curves, rates of land consumption, and residential development factors are used. This model will be referred to as the HCLC method in this paper. The method has recently been documented (2).

The testing and evaluation of these two models were performed by applying them in a common setting. The research was not prompted by the desire to proclaim a winner from among the models tested. These two operational residential-forecasting methods were applied to the city of Toledo, Ohio, which was chosen primarily because it was felt that Toledo's size (1974 population, 332 240) was representative of the city for which forecasting techniques of this kind would be most appropriate. Toledo was also chosen because of my knowledge of the city and its environs. This acquaintance with the area is almost a prerequisite for applying the manual techniques of land use forecasting described. Another reason for choosing Toledo was that a rather extensive information file on a small-area basis is available for two time periods--1965 and 1974. Thus, the two techniques were used to forecast land use for 1974 given the 1965 base.

METHODOLOGICAL PROBLEMS

The two traditional manual-forecasting techniques described here are theoretically simple and operationally straightforward. At the same time, it must be said that, although the allocation process in such models is based on acceptable planning standards, it is also dependent on professional judgment, which can at times be subjective, even though such judgments are buttressed by principles and techniques of planning.

DATA SOURCES

The data for testing these two techniques of land use forecasting came from several sources, chiefly the Bureau of the Census, publications of the Toledo Regional Area Plan for Action (TRAPA), and the city of Toledo. It is important to state that, since these tests were conducted ex post facto, no information beyond 1965 was used. Indeed, great care was taken to completely eliminate all information and data available after 1965, except the total 1974 population, derived exogenously.

MODEL PERFORMANCE AND U-TEST

The U-test, a standardized statistical test, was used to establish the reliability of model forecasts. The U-statistic is a measure of the statistical correlation between two sets of data, whereas the U-test is a statistical-distribution test that measures the agreement between the forecast item and the observed item frequency. The accuracy of the forecast is judged by the magnitude of the U-value. The U-statistic is calculated as follows:

$$U = \{[(1/N)\,\Sigma(S_i - C_i)^2]^{1/2}\}/\{[(1/N)\Sigma(S_i)^2]^{1/2} + [(1/N)\Sigma(C_i)^2]^{1/2}\} \qquad (1)$$

where

S_i = projected value of zone i,
C_i = actual value of zone i, and
N = number of intervals in the distribution.

In general, a value of U less than 0.1 is considered good; a value between 0.1 and 0.3, average; and a value more than 0.3, poor (3).

DSG METHOD

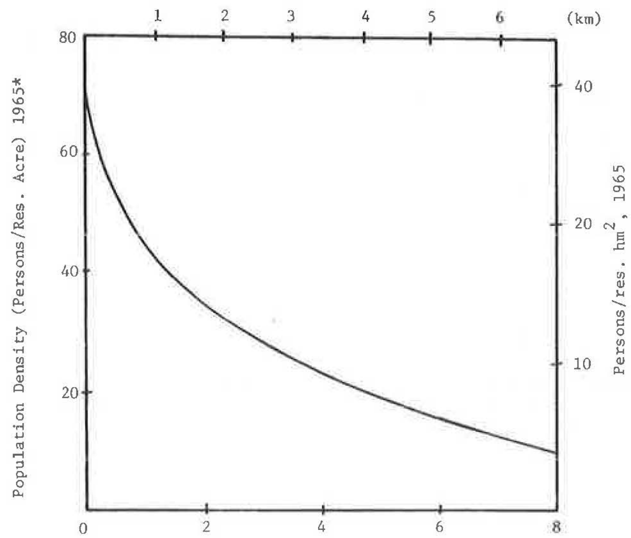
The density-saturation gradient is, as the name suggests, a plot of the residential saturation as a function of distance or travel time from some convenient reference origin--usually the city center. It is a function that can be determined experimentally for any city, although practical difficulties are encountered because of topographical and zoning peculiarities. It is sometimes necessary to define the function separately for a number of sectors of the surrounding metropolis. The only known previous application of this approach has been for the Chicago area. Swerdloff and Stowers (4) later applied it in a test situation to Greensboro, North Carolina, and the procedures detailed in their paper are used here.

The DSG method was applied to the city of Toledo by using airline distance from the high-value corner (HVC) as the key spatial variable. HVC is a point representative of the hypothetical activity center of the central business district (CBD). Figure 1 shows the relationship between 1965 residential density and airline distance from HVC. Each point on this plot represents the residential density for a ring around HVC. The decline in density results from the operation of the competitive land market.

Each ring is defined by the boundaries of all census tracts the centroids of which fall within ±0.5 mile of the distance of the ring from HVC, with the exception of the first, or CBD, ring. The plot indicates a regular decline in residential densities with distance from HVC. The next step is to compute the holding capacity. Mathematically, the holding capacity of an area is defined as the existing population plus the product of vacant, available, and suitable land and the expected residential density. Theoretically, this density is the anticipated average density at which all future residential development will occur.

These values can be developed from an intensive analysis of trends in residential density patterns

Figure 1. Population density by distance bands, 1965.



and zoning policies. For purposes of this investigation, future densities for each census tract are assumed to be those given by the smooth, hand-fitted curve of Figure 1.

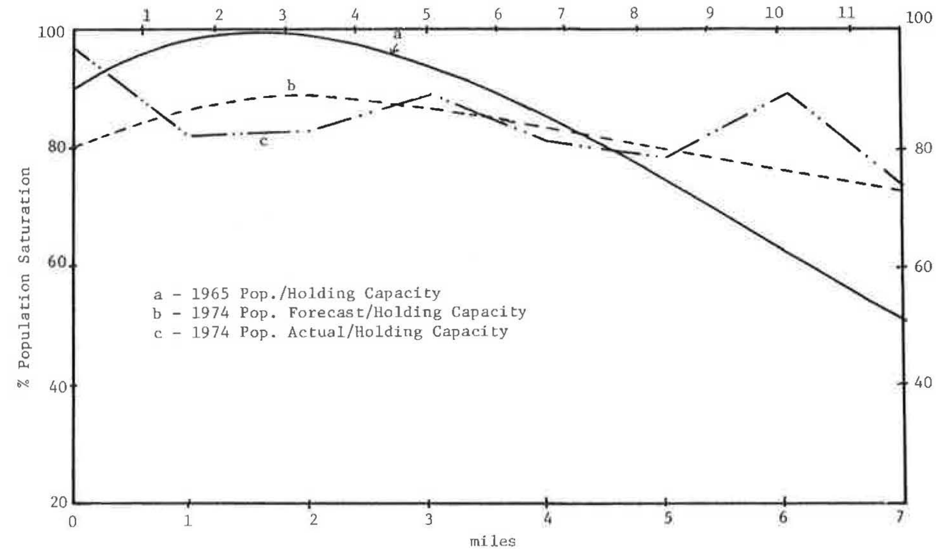
Vacant, suitable land for residential development was estimated from figures available from data for planning areas. Also, from zoning ordinances and zoning plans, it was possible to estimate land available or earmarked for residential use. Once future residential densities and vacant, available land for residential use had been determined, it was possible to compute residential-holding capacities and residential saturations (1965 population versus residential-holding capacity) for each census tract. The latter values were then used to construct the percentage saturation gradient for 1965 (curve a, Figure 2). No particular judgment decisions were needed or used up to this point in the forecasting procedure.

The plot of the 1965 population versus residential-holding capacity conforms very well with the expected plot for an urban area, as shown in Figure 2. The next step was the 1974 projection of the percentage saturation curve, also shown in Figure 2. This is the most critical and subjective step in the forecasting process, since the only restraint on the projected curve is that the area under the new curve account for the existing plus the projected regional growth. The population in the study area grew from a 1964 total of 324 385 to 332 240 in 1974, or a growth of 2.42 percent. From trends of population movement it was generally known that the center city was rapidly losing population and that areas outside the study area were gaining population.

One can proceed in an almost infinite number of ways in establishing an acceptable projection of the percentage saturation gradient for 1974 population. However, it was found useful first to develop a feel for the overall scale of the problem. The following procedural steps were considered in order to determine the 1974 saturation gradient:

1. By using the 1950 and 1960 census figures for population, saturation gradients for 1950 and 1960 were constructed similar to curve a in Figure 2. From these curves it was observed that the population at the city center was declining and the slope of the saturation gradient was becoming flatter.

Figure 2. Percentage saturation gradients for 1965, 1974 forecast, and 1974 actual population by distance bands.



Thus, the pattern of densities prevailing in 1965 represented a kind of equilibrium between the cost of land, building costs, locational requirements, and transportation costs. Indeed, as shown in Figure 3, the 1950, 1960, and 1965 saturation gradients provided a rough estimate of the proportional changes one could expect for a 1974 saturation gradient.

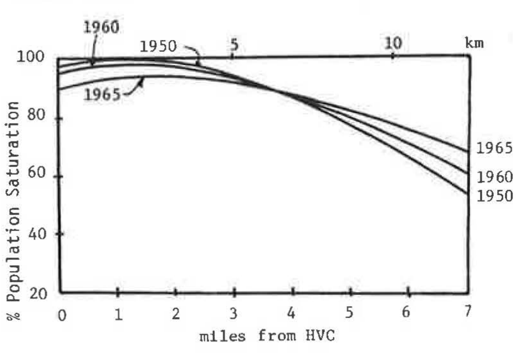
2. Building permits obtained from the city of Toledo for the period 1959-1964 were grouped by census tracts and rings. The increments in housing and thus population were aggregated and used as trends for the 1965-1974 period.

3. The zoning ordinances of the city of Toledo were examined, and census tracts that fell into various categories were aggregated by ring. This helped to set saturation-gradient figures at the ring level.

Based on the results from step 1, a rough 1974 saturation gradient was drawn. This was adjusted to reflect the trend and location of growth obtained from steps 2 and 3. The final adjustment was made to assure that the area under the 1974 curve was commensurate with the 1974 total population.

Several attempts were necessary before a solution that reflected the total 1974 population was obtained. A smooth, hand-fitted curve was then drawn to represent the 1974 saturation gradient (curve b, Figure 2). Multiplying the appropriate ordinate value from this forecast percentage saturation gradient for 1974 by the ring saturation quantities established the forecast population totals by analysis ring.

Figure 3. Percentage saturation gradients for population density for 1950, 1960, and 1965.



The question now remained of distributing these ring totals to individual census tracts. This distribution is dependent on several factors, such as accessibility and water and sewer facilities. In order to measure the strength of the residential-development potential, an activity-allocation process was formulated. Several metropolitan-area transportation studies have used residential-development factors in the past in their activity-allocation process. The specific values assigned to these factors were selected to reflect the comparative impacts that sewer service, water service, accessibility, etc., have on residential growth. Based on these studies, a similar rating procedure was developed for this research that took into account a systematic linear weighting of the following factors: community facilities (sewer, water, school); accessibility (CBD, shopping centers, employment centers, highway and transit systems); and activity patterns (existing land use, recreation).

After the initial distribution from ring totals to census tracts had been performed, two further checks were made: first, to make sure that a particular census tract had not been allotted a population in excess of its residential-holding capacity; and, second, to determine whether a given census tract was in conformity with the applicable zoning ordinance.

HCLC METHOD

The HCLC method combines the concepts of holding capacity, the use of logistic curves, and land-consumption rates in the distribution of an areawide forecast of population to small areas. The HCLC method was applied to the city of Toledo west of the Maumee River to an area identical to that used in the DSG method previously described. The small-area unit used is the census tract. Census tracts that have similar characteristics were grouped into planning areas. Twelve such planning areas were identified.

Table 1 is an inventory of the total acreage, 1965 residential acreage, additional land for residential use, and maximum land available for residential use. The number of dwelling units (DUs) in 1965 (the base year) and the maximum number of DUs

Table 1. Capacity projections of land use by planning area.

Planning Area	Land Use (hm^2) Total	1965 Residential	Additional Residential	Maximum Residential	DUs 1965	Capacity	1965 Percentage of Capacity
Old Orchard	8 838	2531	171	2702	11 531	11 531	100
West Toledo (A)	4 732	2141	30	2171	9 096	9 349	100
West Toledo (B)	4 999	2409	172	2581	7 452	7 452	100
Mayfair	6 457	1428	675	4684	5 127	7 665	66.9
Trilby	8 941	3289	2218	5507	6 212	10 476	59.3
Talmadge	4 162	1671	420	2091	3 150	3 979	79.2
Heatherdowns	12 892	3681	1363	5044	8 183	11 962	68.4
Reynolds Corner	13 041	3351	3186	6537	5 536	11 930	46.4
Airport Highway	6 872	553	1235	1788	797	2 605	30.6
Point Place	5 190	1541	808	2349	4 597	6 116	75.2
Fort Industry	8 810	231	-	231	228	228	100
Inner core					68 785	68 785	100
Lagrange	5 961	1981	75	2056			
Center City	2 090	324	-	324			
Dorr	4 841	2198	-	2198			
North End	4 921	992	-	992			
Old West End	3 355	1731	-	1731			
South Side	7 210	2322	-	2322			

Note: 1 hm^2 = 2.47 acres.

at holding capacity for every planning area are shown.

It was possible to estimate land available or earmarked for residential use from 1965 zoning plans, the land-capability analysis, and 1964 aerial photographs. In the HCLC method, DUs are substituted for population when the holding capacity is calculated. Thus the ratio of DUs in a planning area to the holding capacity determines the stage in the development cycle that the planning area has reached in the base year (1965). It also provides the basis for estimating at which stage the area will be at a future date--in this case, 1974.

The question of establishing the development cycle was taken up next. From previous investigation and analysis, a typical development cycle derived from a logit curve of approximately 50 years was selected (Table 2) and applied to the planning areas to estimate the percentage of growth of DUs in each planning area, depending on the stage of development each area is currently in. This growth is shown in Table 3, which also shows the forecast DUs for 1974. The forecast population for each planning area is shown in Table 4.

The vacancy and occupancy rates adopted in Table 4 were derived by straight-line projections of corresponding 1960 and 1965 figures to 1974. The only information used was the total 1974 population (332 240), derived exogenously. The distribution of the 1974 forecast population by planning areas to census tracts was performed by using the residential-development factors described previously. It may be stated that after the planning-area population had been distributed to census tracts by using the residential-development factors, it was necessary to assure that the zoning ordinances applicable to different areas and census tracts were not violated and also to verify that the residential-holding capacities were not exceeded for any census tract.

Table 2. Development cycle: estimated years required to achieve given stage of development.

Type of Growth	Percentage of Capacity Developed	Annual Growth Rate (%)	Approximate Number of Years in Stage
Very slow	0-10	1	10
Slow	11-20	2	5
Moderate	21-40	3	7
Boom	41-60	4	5
Moderate	61-80	3	7
Leveling off			
Fast	81-90	2	5
Slow	91-100	1	10
Total			49

PERFORMANCE

The U-test was applied to both models and computed at two levels of aggregation, the ring and the planning area. The ring is associated with the DSG method, whereas the HCLC method uses the planning area. U-values are given below for both methods:

Method	U-Value Ring	Planning Area
DSG	0.0383	0.021
HCLC	0.0421	0.034

Since all the values of U are less than 0.1, one could easily acclaim that both methods produced excellent results.

The DSG method is simple, straightforward, and easy to operate even for cities the size of Toledo. The only difficulty was setting up the 1974 density curve. Several trials had to be made before the area under the curve was commensurate with the area population.

The HCLC method was equally simple and straightforward except for the calibration of the logistic curves. It may have been easier to set up these curves and obtain more-accurate growth rates had there been sufficient historical data available.

Overall, the results produced by these two simple models for land use allocation were very promising. Once the data were available, it took roughly 50 person-h to run each model. No attempt was made to keep track of the time required to collect and tabulate the data.

CONCLUSIONS

The two traditional manual methods for forecasting land use described in this paper are sufficiently accurate to be recommended for small and medium-sized cities. Both methods almost force the analyst to become intimately familiar with the study area, its zoning ordinances, its physical characteristics, and its growth trends before attempting to fore-

Table 3. Forecast growth of DUs in planning areas, 1965-1974.

Planning Area	DUs in 1965	Percentage of Growth by Annual Growth Rate[a]							1974 Forecast DUs
		1 Percent	2 Percent	3 Percent	4 Percent	3 Percent	2 Percent	1 Percent	
Old Orchard	11 531	No expansion							11 531
West Toledo (A)	9 096	No expansion							9 096
West Toledo (B)	7 452	No expansion							7 452
Mayfair	5 127					3/4[b]	2/5		6 371
Trilby	6 212				4/1	3/7	2/1		8 104
Talmadge	3 150					3/1	2/5	1/3	3 690
Heatherdowns	8 183					3/4	2/5		10 168
Reynolds Corner	5 536				4/3	3/6			7 436
Airport Highway	797			3/3	4/6				1 102
Point Place	4 597					3/2	2/5	1/2	5 493
Fort Industry	228	No expansion							228
Inner core	68 785		3/9 (decline)						51 589

[a]Percentage of growth per year per number of years. [b]Denotes 3 percent growth per year over a four-year period.

Table 4. Forecast and actual population, 1974.

Planning Area	1974 Forecast DUs	Vacancy Rate (%)	Occupancy Rate (persons/DU)	1974 Forecast Population		Actual 1974 Population	Ratio Forecast/ Actual
				Raw	Final		
Old Orchard	11 531	4.1	2.6	28 751	30 220	27 530	1.10
West Toledo (A)	9 096	3.1	2.7	23 798	25 014	25 111	1.00
West Toledo (B)	7 452	3.4	2.8	20 156	21 186	21 395	0.99
Mayfair	6 371	3.0	3.0	18 540	19 487	18 474	1.05
Trilby	8 104	2.6	3.1	24 471	25 721	29 935	0.86
Talmadge	3 690	2.6	2.8	10 065	10 579	11 314	0.94
Heatherdowns	10 168	3.4	3.0	29 469	30 975	36 574	0.86
Reynolds Corner	7 436	2.7	3.0	21 704	22 813	21 151	1.08
Airport Highway	1 102	3.6	3.0	53 187	3 350	4 387	0.76
Point Place	5 493	2.5	3.1	16 602	17 450	16 652	1.04
Fort Industry	228	2.5	3.3	733	770	514	1.50
Inner core	51 589	4.2	2.4	118 612	124 675	119 203	1.05
				316 088	332 240	332 240	

cast. This is considered a positive feature of the methods. In any case, the methods of analysis described here are useful tools that can stand on their own or even serve as checks on the reasonableness of forecasts produced by the more-sophisticated computer-oriented models.

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