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System-Dynamics Approach to Transportation Planning in Developing Regions

A.G. HOBEIKA, G. BUDHU, AND T.K. TRAN

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.

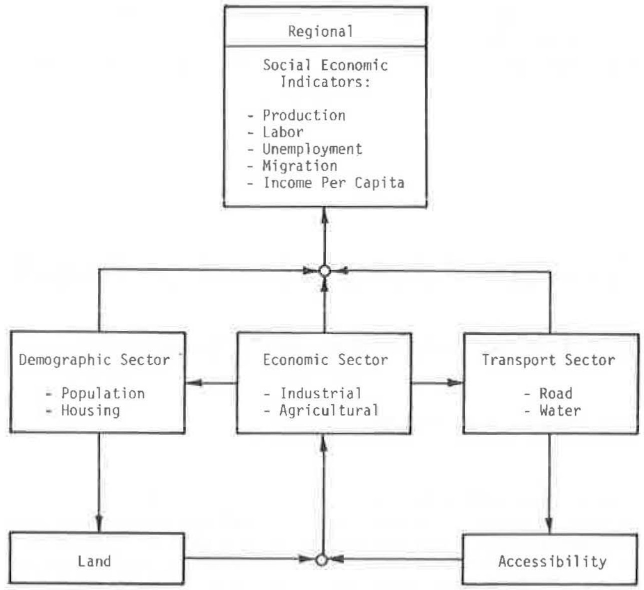
MODEL FORMULATION

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.

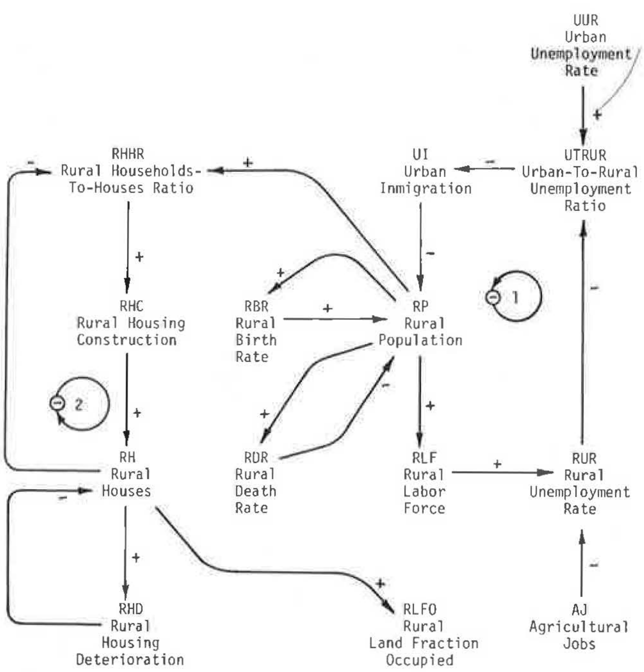
Demographic Sector

The demographic sector is represented by the population and the housing components. The regional population level determines the labor force, unemploy-

ment, 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

Figure 2. Causal relationships within demographic sector.



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.

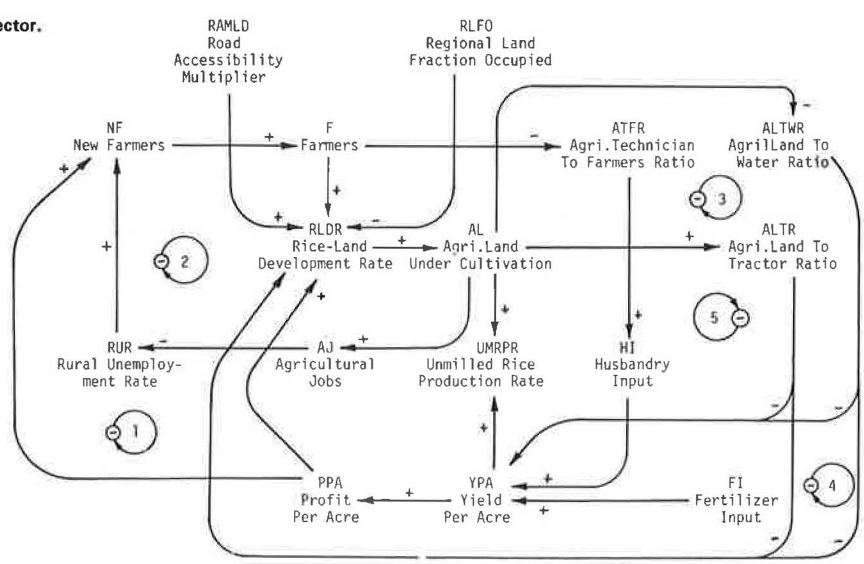
Economic Sector

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:

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

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:

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

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:

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

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:

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

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

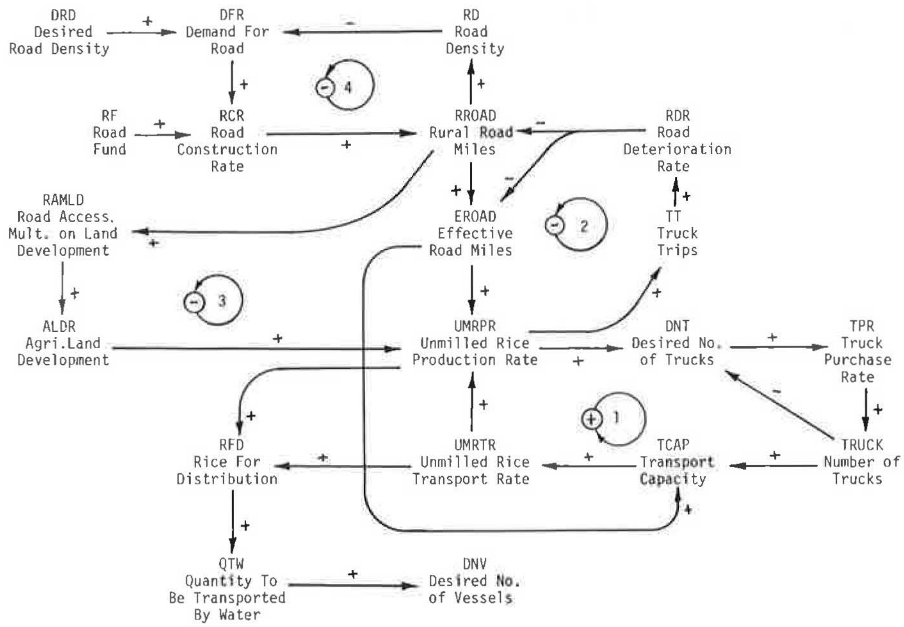


Figure 4. Causal relationships within transportation sector.

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:

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

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

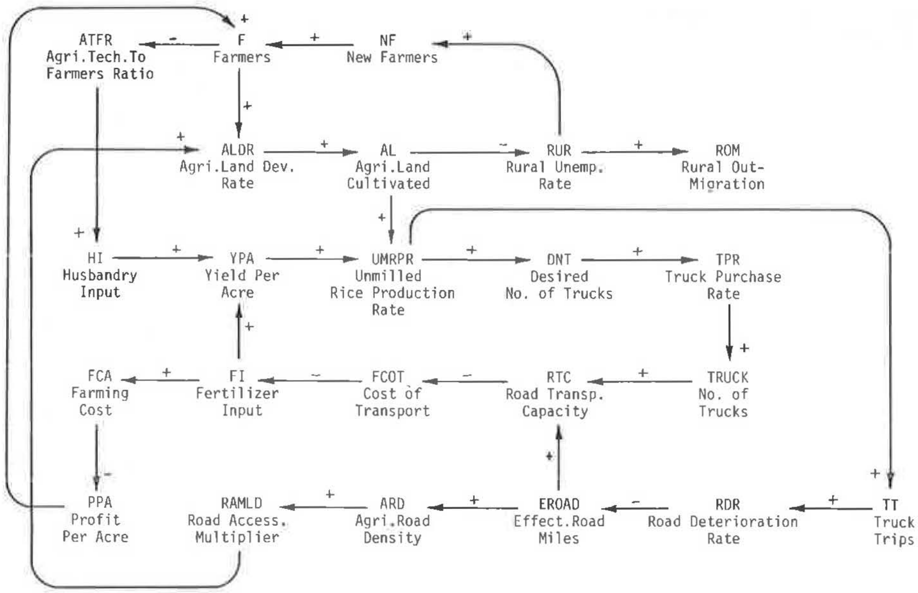
Figure 5 shows the simplified causal diagram of the coupling of the three sectors. The important intersectoral impacts are recognized through the following variables: urban in-migration, unmilled-rice-production rate, cost of transport, and the agricultural-land-development rate. The comprehensive mathematical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

	Present Worth (G$)				
	Costs (G$)				
Strategy	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.

	Strategy		
Economic Indicator	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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